Workshop on Helicopter Health and Usage Monitoring Systems, Melbourne, Australia, February 1999 - Part 2

Graham F. Forsyth (Editor)

DSTO-GD-0197 (Part 2)

Workshop on Helicopter Health and Usage Monitoring Systems, Melbourne, Australia, February 1999 - Part 2

Graham F. Forsyth (Editor)

Airframes and Engines Division
Aeronautical and Maritime Research Laboratory

DSTO-GD-0197 (Part 2)

ABSTRACT

Over the last 10 years, helicopter Health and Usage Monitoring Systems (HUMS) have moved from the research environment to being viable systems for fitment to civil and military helicopters. In the civil environment, the situation has reached the point where it has become a mandatory requirement for some classes of helicopters to have HUMS fitted. Military operators have lagged their civil counterparts in implementing HUMS, but that situation appears set to change with a rapid increase expected in their use in military helicopters.

A DSTO-sponsored Workshop was held in Melbourne, Australia, in February 1999 to discuss the current status of helicopter HUMS and any issues of direct relevance to military helicopter operations. This second part contains a list of those attending and a number of papers not received in time for publication before the event.

RELEASE LIMITATION

Approved for public release

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE & TECHNOLOGY ORGANISATION

DSTO

DTIC QUALITY INSPECTED 4

19990415024

Contents

1. Introduction

Helicopters have a higher rate of accidents due to technical causes than public transport fixed-wing aircraft, so it should come as no surprise that equipment capable of detailed monitoring of critical helicopter functions is now routinely fitted to medium and large-size helicopters used by civil operators. This equipment is usually referred to by the name "Health and Usage Monitoring Systems" (HUMS) although most of the HUMS in service concentrate mainly on assessing the health of the helicopter and have only rudimentary usage monitoring.

Military operators have been slower than civil operators to implement HUMS in their fleets. However, there are good reasons for this. Military helicopters, in general, are operated at a much lower rate of effort (ROE), expressed as flight hours per year, and are kept in service for a much longer period. Military operators also have less need to minimize training and test flying than civil operators since these types of flying may be regarded by the military as a legitimate function rather than as a deviation from the main purpose. These factors mean that, although current HUMS may show similar rates of return for both military and civil helicopters, when expressed as return per unit flying time, military operators have a lower rate of return than civil operators per unit of calender time.

This difference means that military operators are showing more interest in improving the usage monitoring component of these systems.

It is noticeable that the amount of time by which military operators lagged their civil counterparts in installing accident data recorders is much greater than that for the installation of HUMS.

The papers listed in the timetable, in a following section, were presented at a Workshop coordinated by the Airframes and Engines Division of DSTO Aeronautical and Maritime Research Laboratory in Melbourne, Australia, on February 16 and 17, 1999. Papers were presented by authors from HUMS manufacturers, research institutions, helicopter operators, and other organisations. Most of the papers presented at the Workshop have been included in a proceedings document, published as DSTO-GD-0197, in the format provided by their respective authors. Some papers, however, were not available for inclusion in that document at the time of its publication and they are included herein, along with an attendance list and the final timetable.

2. Acknowledgments

The Helicopter Health and Usage Monitoring System (HUMS) Workshop was arranged via a committee comprising:-

Graham Forsyth, as convenor,
Neil Kennedy, representing RAAF Williams,
Paul Marsden,
Graeme Messer,
Luther Krake, and
Bill Clark (who is on secondment from the US Navy)

Additionally, this committee needs to thank Christine Vavlitis for arranging the barbeque, Jim Nichols from Boeing for organising the video feed for those unable to fit in the conference room, staff from the AED office for attending to the registrations, arranging coffee and various odd jobs, Domenico Lombardo for directing and guiding the bus morning and evening, and almost every other staff member of the Propulsion area of AED for helping with the escorting of visitors.

3. Final Timetable

Time/Chair		Day 1 - Tuesday 16 February		
0830 – 0900		Registration		
0900 – 0915		**Official Welcome – Dr Bill Schofield, Director AMRL**		
0915 – 0955	Graham Forsyth	**John Gill** **Rick Muldoon**	BFGoodrich US Navy	Integrated Mechanical Diagnostics (IMD) HUMS *Page 7* ♦
0955 – 1020		**David Horsley**	RAF AMDS, UK	Introduction of HUMS into the RAF ♦
1020 – 1035		**Keith Mowbray**	Helitune, UK	"Modular Distributed HUMS – an Overview" *Page 17*
1035 – 1100		Morning Tea Break		
1100 – 1140	Dennis Helie (USA)	**Charles Trammel,** Gerald Vossler	Smiths Industries	"UK Ministry Of Defence Health and Usage Monitoring System (HUMS)" *Page 23*
1140 – 1210		**Pierre Feraud,** **Phillipe Lubrano**	Eurocopter, France	"Commitments of the Helicopter Manufacturer Regarding HUMS Activities" ♦
1210 – 1235		**J.W. Bird,** M.F. Mulligan, J.D. MacLeod, Capt D Little	IAR/NRC, Can(3) DND/ATESS Canada	"Developments in Non-intrusive Diagnostics for Engine Condition Monitoring" *Page 203*
1235 – 1335		Lunch		
1335 – 1440		*AMRL Technical Site Tours (AOSC, HTTF, SETH)*		
1440 – 1510	LCDR G. Williams	**Larry Dobrin**	Chadwick-Helmuth, USA	"Health Monitoring of Helicopters - Case Histories of Benefits" *Page 43*
1510 – 1540		**David Blunt,** Peter O'Neill, Brian Rebbechi	AMRL, RAN-NALMS, AMRL	"Vibration Monitoring Of Royal Australian Navy Helicopters" *Page 49*
1540 – 1605		*Afternoon Tea Break*		
1605 – 1635	Paul Howard (USA)	M.C. Havinga, **C.J. (Nelis) Botes**	AMS, South Africa	"Health and Usage Monitoring System for the Hawk Aircraft" *Page 217*
1635 – 1705		**Charlie Crawford**	GTRI, USA	"HH-60G Mission Usage Spectrum Survey Methodology Overview" *Page 57*
1705 – 1730		**Graham Forsyth**	AMRL	"An Econometric Model for HUMS Cost Benefit Studies" *Page 75*

Time/Chair		Day 2 – Wednesday 17 February		
0815 – 0830		Registration for Wednesday-only attendees		
0830 – 0850	James O'Farrell	**Brian Rebbechi** Albert Wong	AMRL	Machine Dynamics ♦
0850 – 0930		**Jarek Rosinski**	Design Unit - Gear Technology Centre, Newcastle, UK	Gear Noise and Vibration – Research at UK Gear Technology Centre ♦
0930 – 1000		**Robert Cant**	Vibro-Meter, UK	"ROTABS: Re-Writing the Manual on Rotor Track and Balance" *Page 89*
1000 – 1030		**Yujin Gao,** R. B. Randall	Uni of NSW	"Detection of Bearing Faults in Helicopter Gearboxes" *Page 99*
1030 – 1100		Morning Tea Break		
1100 – 1140	LTCOL O.E. Aberle	**John F. Reintjes**	NRL, USA	"LASERNET Machinery Monitoring Technology" *Page 113*
1140 – 1210		**Paul Howard,** John F. Reintjes	Paul L. Howard Ent. NRL, USA	"A Straw Man for the Integration of Vibration and Oil Debris Technologies" *Page 131*
1210 – 1225		**Grier McVea**	AMRL	Sensitivity of Oil Debris Monitor in S-70A-9 Intermediate GB. ♦
1225 – 1340		*Lunch – BBQ*		
1340 – 1410	CDR Chris Fealy	**C.J. (Nelis) Botes**	AMS, South Africa	"Health and Usage Monitoring System for the Denel Aviation Rooivalk Attack Helicopter" ♦
1410 – 1440		**Bill Hardman,** Andy Hess	NAWC AD, USA	"SH-60 Helicopter Integrated Diagnostic Systems (HIDS) Program Experience and Results of Seeded Fault Testing." *Page 181*
1440 – 1455		**Ben Parmington**	AMRL	Lubrication Oil Debris Monitoring Program at AMRL ♦
1455 – 1510		**Domenico Lombardo**	AMRL	"Helicopter Structural Usage Monitoring Work at DSTO Airframes and Engines Division" *Page 137*
1510 – 1540		**Alan Draper**	MOD PE, UK	"Fatigue Usage Monitoring in UK Military Helicopters" *Page 153*
1540 – 1610		*Afternoon Tea Break*		

1610 – 1650		David J. White	AeroStructures USA	"Structural Usage Monitoring Using the MaxLife System" *Page 167*♠
1650 – 1710	Graham Forsyth	Peter Frith	AMRL	Engine Gas Path Condition Assessment ♦
1710 – 1720		*Closing Session*		
1900 – 1945		*Pre-dinner drinks – Observation Deck, Rialto on Collins*		
1945 – 2315		*Conference Dinner – Oriel Room, Rialto on Collins*		

Page Numbers quoted are those of the paper in the Proceedings published as DSTO-GD-0197.

♦ indicates that this paper or the presentation slides from this paper are included in this document.

♠ indicates a paper where some additional slides to those in DSTO-GD-0197 are included in this document.

The timetable was prepared on behalf of the HUMS Workshop committee by Graeme Messer.

4. Attendance List

The following table was prepared from registration details supplied by those persons present. It does not include a considerable number of AMRL and ADF staff who attended only part of the conference or who did not complete a registration form.

Name	Function	Affiliation	Telephone/Fax/Email
Aberle, LTCOL O. E. (Otto)	SO1 Logistics	HQ Aviation Support Group Oakey QLD 4401	+61 (7) 4691 9050 Fax: +61 (7) 4691 9010
Becker, Andrew	Machine Dynamics	AMRL, Airframes and Engines Division	+61 (3) 9626 7382 Fax: +61 (3) 9626 7083 Andrew.Becker@ dsto.defence.gov.au
Betts, Captain Travis	Rotary Wing Systems	DGTA RAAF Williams Laverton VIC 3027	+61 (3) 9256 3608 TWBetts@ raaf.defence.gov.au
Bird, Jeff * #	Structures, Materials & Propulsion Laboratory	NRC Canada Ottawa, K1A 0R6 Canada	+1 613 993 2214 Fax: +1 613 957 3281 jeff.bird@nrc.ca
Blunt, David *	Machine Dynamics	AMRL, Airframes and Engines Division	+61 (3) 9626 7577 Fax: +61 (3) 9626 7083 David.Blunt@ dsto.defence.gov.au
Boeske, FLGOFF E. John		Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7974 Fax: +61 (7) 4691 7810 EJBoeske@ raaf.defence.gov.au
Botes, C.J. (Nelis) *	Manager: Aircraft Systems	Analysis, Management & Systems (Pty) Ltd South Africa	+27 11 315 1002 Fax: +27 11 315 1645 nelis@ams.co.za
Bransfield, Peter	President	Altair Avionics Norwood MA 02062 USA	+1 781 762 8600 Fax: +1 781 762 2287 bransfield@ altairavionics.com
Brockhurst, MAJ Scott		Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7840 Fax: +61 (7) 4691 7810 srbrockh@ raaf.defence.gov.au
Cant, Robert *	Project Manager	Vibro-Meter, Stockport, Cheshire SK7 5BW UK	+44 161 483 0814 Fax: +44 161 483 2850 Robert_Cant@ vibro-meter.co.uk
Carlson, Mal	Account Executive	Teledyne Controls Greensborough VIC 3088	+61 (3) 9435 1084 Fax: +61 (3) 9435 1084 malc@ melbpc.org.au

Name	Function	Affiliation	Telephone/Fax/Email
Cartledge, Dr Helen	Research Scientist and Tribologist	WSD, DSTO PO Box 1500 Salisbury SA 5108 Australia	+61 (8) 8259 5174 Fax: +61 (8) 8259 6247 Helen.Cartedge@ dsto.defence.gov.au
Casper, George	Director, Asia Pacific	Teledyne Controls Los Angeles, CA 90064 USA	+1 310 442 4155 Fax: +1 310 442 4324 George_P._Casper@ Teledyne.com
Christian, Dr. Thomas F.	Chief, Engineering Functional Support Office	WR-ALC/LUE Robins Air Force Base Georgia 31098-1622 USA	+1 912 926 9343 Fax: +1 912 926 4911
Clark, Bill ^	Helicopter Life Assessment	AMRL, Airframes and Engines Division	+61 (3) 9626 7360 Fax: +61 (3) 9626 7083 Bill.Clark@ dsto.defence.gov.au
Crawford, Charles C. (Charlie) *	Chief Engineer	Aerospace & Transportation Lab GTRI, Smyrna GA 30080 USA	+1 770 528 7052 Fax: +1 770 528 3271 charlie.crawford@ gtri.gatech.edu
Dammann, Keith E.	Mechanical Engineer	WR-ALC/LUHE Robins Air Force Base Georgia 31098-1622 USA	+1 912 926 1842 Fax: +1 912 926 4911 kdammann@ lu.robins.af.mil
Di Pietro, CMDR Vince	Deputy Commander Aviation Operations	COMAUSNAVAIR Nowra	+61 (2) 4421 1758 Fax: +61 (2) 4421 1353
Dickinson, Travis		AMRL, Airframes and Engines Division	+61 (3) 9626 7164 Travis.Dickinson@ dsto.defence.gov.au
Dobrin, Larry *	Director of Business Development, On-Board Systems	Chadwick Helmuth El Monte, California 91731 USA	+1 626 575 6161 Fax: +1 626 350 4236 larryd@ chadwick-helmuth.com
Doke CAPT Rob #	Integrated Health Monitoring	ATESS 8Wing Trenton Astra, Ontario CANADA K0K 2T0	+1 613 392 2811 Fax: +1 613 965 3165 ihm@blvl.igs.net
Draper, Alan *#	Deputy Director of Helicopter Policy	DHP, MOD Abbeywood Bristol B534 8JH UK	+44 117 913 4584 Fax: +44 117 913 4592 dhp-h-pol2@ dawn.pe.mod.uk
Dunn, AJ		Not Known	Not Known
Dutton, Scott	Helicopter Life Assessment	AMRL, Airframes and Engines Division	+61 (3) 9626 7575 Fax: +61 (3) 9626 7083 Scott.Dutton@ dsto.defence.gov.au

Name	Function	Affiliation	Telephone/Fax/Email
Eady, SQNLDR Chris #	Logistics (Op Reqs)1e	RAF Brampton Huntingdon PE18 8QL UK	+44 1480 52151 Fax: +44 1480 413563 ce@ logs4raf.demon.co.uk
Ewen, Steve	Sales/Marketing Manager	Amtec Avionics Int. Condell Park, NSW 2200	+61 (2) 9791 0288 Fax: +61 (2) 9791 0050
Fealy, CMDR Chris	OIC RWS	DGTA, RAAF Williams, Laverton VIC	+61 (3) 9256 3808 Fax: Cafealy@ raaf.defence.gov.au
Feraud, Pierre *	HUMS Program Director	EuroCopter France, 13725 Marignane	+33 4 42 85 96 91 Fax: +33 4 42 85 99 55
Fisher, Sam	Research Leader Propulsion	AMRL, Airframes and Engines Division	+61 (3) 9626 7550 Fax: +61 (3) 9626 7083 Sam.Fisher@ dsto.defence.gov.au
Forsyth, Graham *	Helicopter Life Assessment	AMRL, Airframes and Engines Division	+61 (3) 9626 7558 Fax: +61 (3) 9626 7083 Graham.Forsyth@ dsto.defence.gov.au
Fraser, Ken	Head, Helicopter Life Assessment	AMRL, Airframes and Engines Division	+61 (3) 9626 7590 Fax: +61 (3) 9626 7083 Ken.Fraser@ dsto.defence.gov.au
Frew, Don		Marconi Electronic Systems, Portsmouth Hampshire PO3 5PH UK	+44 1705 22 6300 Fax: +44 1705 22 7133
Friend, Doug	Research Engineer II	Aerospace & Transportation Lab GTRI, Smyrna GA 30080 USA	+1 770 528 7924 Fax: +1 770 528 3271 douglas.friend@ gtri.gatech.edu
Frith, Peter *	Head, Engine Performance	AMRL, Airframes and Engines Division	+61 (3) 9626 7695 Fax: +61 (3) 9626 7083 Peter.Frith@ dsto.defence.gov.au
Galati, Tony		AMRL, Airframes and Engines Division	+61 (3) 9626 7296 Fax: +61 (3) 9626 7083 Tony.Galati@ dsto.defence.gov.au
Gill, Dr John *	Simulation & Algorithm Development	BFGoodrich, Bedford, MA 01730 USA	+1 781 276 1412 Fax: +1 781 275 5035 jgill@aisma.bfg.com

Name	Function	Affiliation	Telephone/Fax/Email
Green, Captain Robert		Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7753 Fax: +61 (7) 4691 7810 RJGreen@ raaf.defence.gov.au
Gregoski, MAJ Ed	US Army Far East	Tokyo	Fax: +81 311 768 4886
Hahn, Dr Eric	Professor, School of Mechanical & Manufacturing Engineering	DSTO CoE in Vibration Analysis Uni of NSW	+61 (2) 9385 4142 Fax: +61 (2) 9663 1222 e.hahn@unsw.edu.au
Halstead, Russell L.	Flight Test Engineer	Sikorsky Aircraft Corp Stratford Conn. 06497-9129 USA	+1 203 386 7244 Fax: +1 203 386 7443
Hardman, Bill J *	Project Engineer (HIDS)	NAWCAD Patuxent River MD 20670-1534 USA	+1 301 757 0508 Fax: +1 301 757 0542 HardmanWJ@ navair.navy.mil
Hawker, EC (Ted)		CAA of NZ, Lower Hutt, New Zealand	+64 4 560 9535 Fax: +64 4 560 9481 HawkerT@caa.govt.nz
Helie, Dennis G.	PMA-261 Deputy Program Manager H53 & VH Helicopters	PEO ASWASM US Navy Patuxent River, MD 20670-1547 USA	+1 301 757 5784 Fax: +1 301 757 5109 HelieDG.JFK@ navair.navy.mil
Horsley, FLTLT Dave *	HUMS & GSS Team Leader	AMDS Huntingdon PE17 2PY UK	+44 1480 52451 x7761 Fax: +44 1480 446 565 Hums@logistics.org.uk
Howard, Paul *	US Navy Consultant on LaserNet	Paul L Howard Ent. PO Box 362 Newmarket NH 03857 USA	+1 603 659 4956 Fax: +1 603 659 2592 PLHoward@aol.com
Jobson, LTCOL Keith	Chief Engineer	Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7801 Fax: +61 (7) 4691 7810 KAJobson@ raaf.defence.gov.au
Johnson, MAJ Craig		Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7750 Fax: +61 (7) 4691 7810 CDJohns1@ raaf.defence.gov.au
Kennedy, Neil	Senior Officer (Tech) Grade C WGCDR (retired)	DAIRENG- SCI4C DGTA RAAF Williams Laverton VIC 3027	+61 (3) 9256 3546 Fax: +61 (3) 9256 3540 Nskenned@ raaf.defence.gov.au
King, Jeremy	Aircraft Structural Integrity	DGTA RAAF Williams Laverton VIC 3027	+61 (3) 9256 3766 jbking@ raaf.defence.gov.au

Name	Function	Affiliation	Telephone/Fax/Email
Klein, Ed	Squirrel Logistics Manager	Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7851 Fax: +61 (7) 4691 7810
Konopka, Henry	Supervisor, H60 Airframe Structure	Sikorsky Aircraft Corp Stratford Con 06615-9129 USA	+1 203 386 4725 Fax: +1 203 386 3717 HKonopka@ sikorsky.com
Kous, LT Nick	Rotary Wing Systems	DGTA RAAF Williams Laverton VIC 3027	+61 (3) 9256 3533 Fax: +61 (3) 9256 3488
Krake, Luther	Helicopter Life Assessment	AMRL, Airframes and Engines Division	+61 (3) 9626 7112 Fax: +61 (3) 9626 7083 Luther.Krake@ dsto.defence.gov.au
Last, SQNLDR Andrew	Aircraft Structural Integrity 4	DGTA RAAF Williams Laverton VIC 3027	+61 (3) 9256 3535 Fax: +61 (3) 9256 3488 awlast@ raaf.defence.gov.au
Lombardo, Domenico *	Helicopter Life Assessment	AMRL, Airframes and Engines Division	+61 (3) 9626 7660 Fax: +61 (3) 9626 7083 Domenico.Lombardo@ dsto.defence.gov.au
Lubrano, Phillippe *	Marketing Manager	EuroCopter France, 13725 Marignane	+33 4 42 85 96 91 Fax: +33 4 42 85 99 55
Marsden, Paul	Machine Dynamics	AMRL, Airframes and Engines Division	+61 (3) 9626 7571 Fax: +61 (3) 9626 7083 Paul.Marsden@ dsto.defence.gov.au
McAloney, Captain Peter	Design Engineer	Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7770 Fax: +61 (7) 4691 7810 pcmcalon@ raaf.defence.gov.au
McGeehan, CAPT Andy	Rotary Wing Systems 1B	DGTA RAAF Williams Laverton VIC 3027	+61 (3) 9256 3509 Fax: +61 (3) 9256 3488 anmcgeeh@ raaf.defence.gov.au
McVea, Grier *	Fuel Science and Tribology	AMRL, Airframes and Engines Division	+61 (3) 9626 7322 Fax: +61 (3) 9626 7083 Grier.Mcvea@ dsto.defence.gov.au
Messer, Graeme	Engine Performance	AMRL, Airframes and Engines Division	+61 (3) 9626 7276 Fax: +61 (3) 9626 7083 Graeme.Messer@ dsto.defence.gov.au

Name	Function	Affiliation	Telephone/Fax/Email
Mirabella, Leo		AMRL, Airframes and Engines Division	+61 (3) 9626 7809 Leo.Mirabella@ dsto.defence.gov.au
Molent, Loris	Airframes & Engines Division	AMRL, Airframes and Engines Division	+61 (3) 9626 7653 Fax: +61 (3) 9626 7072 Lorrie.Molent@ dsto.defence.gov.au
Mowbray, Keith *	Future Business Manager	Ultra Electronics (Helitune) Cheltenham GL51 9PG UK	+44 1242 225 012 Fax: +44 1242 221 167 keith_mowbray@ ueed.co.uk
Muldoon, LCDR Richard C. (Rick) *	Integrated Mechanical Diagnostics IPT Leader	PEO ASWASM US Navy Patuxent River MD 20670-1547 USA	+1 301 757 5779 Fax: +1 301 757 5109 Muldoonrc@ navair.navy.mil
Norrie, MAJ Mal	AIR 87 Armed Rec. Helicopter Project	Defence Acq. Org. CP3-1-Bay5 Campbell Park ACT 2600	+61 (2) 6266 4760 fax: +61 (2) 6266 4117 Mal.Norrie@ dao.defence.gov.au
O'Farrell, James	Vice-Director Helicopter Programs	Vibro-Meter Aerospace Div. 1701 Fribourg Switzerland	+41 26 407 1582 Fax: +41 26 402 3662 jofa@ vmfr.vibro-meter.ch
Page, FLTLT John M	A25AV	Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7866 Fax: +61 (7) 4691 7810 JMPage@ raaf.defence.gov.au
Parmington, Ben *	Fuel Science and Tribology	AMRL, Airframes and Engines Division	+61 (3) 9626 7559 Fax: +61 (3) 9626 7083 Ben.Parmington@ dsto.defence.gov.au
Pawsey Peter	Australian Agent for Helitune, Altair, etc.	Rotor & Wing Aviation Services P/L PO Box 6262, Cairns, QLD, 4870	+61 (7) 4034 2827 Fax: +61 (7) 4034 2827 ppawsey@ ozemail.com.au
Power, Alan	Head, Fuel Science and Tribology	AMRL, Airframes and Engines Division	+61 (3) 9626 7319 Fax: +61 (3) 9626 7083 Alan.Power@ dsto.defence.gov.au
Preston, Dr Peter	Chief, Airframes and Engines Division	AMRL	+61 (3) 9626 7666 Fax: +61 (3) 9626 7093 Peter.Preston@ dsto.defence.gov.au
Prior, David	Chief Executive Officer	Amtec Avionics Int. Condell Park, NSW 2200	+61 (2) 9791 0288 Fax: +61 (2) 9791 0050

Name	Function	Affiliation	Telephone/Fax/Email
Rebbechi, Brian *	Machine Dynamics	AMRL, Airframes and Engines Division	+61 (3) 9626 7592 Fax: +61 (3) 9626 7083 Brian.Rebbechi@ dsto.defence.gov.au
Reedy, E.		Not Known	Not Known
Reintjes, Dr John F *	LaserNet Project	Naval Research Laboratory Washington, DC 20375 USA	+1 202 767 2175 Fax: +1 202 404 7530 reintjes@ ccf.nrl.navy.mil
Rosinski, Dr Jarek *	Design Unit	Gear Technology Centre Newcastle-upon-Tyne UK	+44 191 222 6096 Fax: +44 191 222 6194 jarek.rosinski@ ncl.ac.uk
Schmidt, LCDR Mel		HS816 Sqn, Nowra	+61 (2) 4421 1493 Fax: +61 (2) 4421 1443 Melvyn.Schmidt.12993 8@ navy.gov.au
Sinclair, LCDR Chris	Maritime Aviation 2	Aerospace Development Branch RAN	+61 (2) 6265 3018 Fax: +61 (2) 6265 3195 Chris.Sinclair@ cbr.defence.gov.au
Skuja, Nina	Principle Engineer	AeroStructures Aust., Level 14, 222 Kingsway South Melb VIC 3205	+61 (3) 9686 8081 Fax: +61 (3) 9696 8195 Nina.Skuja@ aerostructures.com.au
Trammel, Charles H.*	Director, HUMS/DMST	Smiths Industries Grand Rapids, 49512-1991 USA	+1 616 241 7892 Fax: +1 616 241 7667 Trammel_Chuck@ si.com
Wagstaff, Ian	Red Hawk Chief Designer	Denel, Republic of South Africa	+27 11 927 3427 Fax: +27 11 395 1944
Wainwright, Rodney	President	Wainwright Technologies Wintergreen, VA 22958 USA	+1 804 361 1480 Fax: +1 804 361 1480 102676.1057@ compuserve.com
Wedding, Captain Tim	Kiowa Logistics Manager	Army Aircraft Logistics Management Squadron, Oakey QLD 4401	+61 (7) 4691 7771 Fax: +61 (7) 4691 7810
Wenyi Wang	Machine Dynamics	AMRL, Airframes and Engines Division	+61 (3) 9626 7138 Fax: +61 (3) 9626 7083 Wenyi.Wang@ dsto.defence.gov.au

Name	Function	Affiliation	Telephone/Fax/Email
White, David *	Vice President, Program Development	AeroStructures Inc., Arlington VA 22202-4102 USA	+1 703 413 1600 Fax: +1 703 413 1611 dwhite@ aerostructures.com
Wicks, Dr Bryon J	Head, Mechanical Integrity	AMRL, Airframes and Engines Division	+61 (3) 9626 7521 Fax: +61 (3) 9626 7083 Bryon.Wicks@ dsto.defence.gov.au
Williams, LCDR Greg	DAIRENG-RWS1	DGTA, RAAF Williams, Laverton VIC 3027	+61 (3) 9256 3760 Fax: +61 (3) 9256 3488 Gmwillia@ raaf.defence.gov.au
Wong, Albert	Head, Machine Dynamics	AMRL, Airframes and Engines Division	+61 (3) 9626 7636 Fax: +61 (3) 9626 7083 Albert.Wong@ dsto.defence.gov.au
Wright SQNLDR Steve	Aero Eng 3	RNZAF Wellington 6000 New Zealand	+64 4 498 6527 Fax: +64 4 498 6818 AE3@hq.af.mil.nz
Wright, Mary Gayle		L3 Communications	+1 941 377 5500 Fax: +1 941 377 5591 Mary.Gayle.Wright@ l-3com.com
Yujin Gao *	DSTO Centre of Expertise in Vibration Analysis	University of NSW	+61 (2) 9385 4128 Fax: +61 (2) 9663 1222 Yujin.Gao@ unsw.edu.au

Attendance List

* indicates a speaker,

^ currently on secondment to AMRL, from NAWCAD, Patuxent River.

Attended TTCP AER-TP3 meeting afterwards.

5. Papers Included in this Document

The following pages contain either the paper or a copy, as two slides per page, of the PowerPoint[1] Presentations of those papers not included in the original Proceedings. As well, one presentation is included where the paper was included in the original Proceedings and some additional slides are published for one presentation.

The presentations have been included in the order determined by the timetable of a previous section.

Author/Presenter	Affiliation/Country	Title or Topic	Page
John Gill Rick Muldoon	BFGoodrich US Navy	Integrated Mechanical Diagnostics (IMD) HUMS	* 19
David Horsley	RAF AMDS, UK	Introduction of HUMS into the RAF	35
Pierre Feraud, Phillipe Lubrano	Eurocopter, France	"Commitments of the Helicopter Manufacturer Regarding HUMS Activities"	51
Brian Rebbechi Albert Wong	AMRL	Machine Dynamics	63
Jarek Rosinski	Design Unit - Gear Technology Centre, Newcastle, UK	Gear Noise and Vibration – Research at UK Gear Technology Centre	75
Grier McVea	AMRL	Sensitivity of Oil Debris Monitor in S-70A-9 Intermediate GB	97
C.J. (Nelis) Botes	AMS, South Africa	"Health and Usage Monitoring System for the Denel Aviation Rooivalk Attack Helicopter"	103
Ben Parmington	AMRL	Lubrication Oil Debris Monitoring Program at AMRL	115
David J. White	AeroStructures USA	"Structural Usage Monitoring Using the MaxLife System" (Additonal slides only)	123
Peter Frith	AMRL	Engine Gas Path Condition Assessment	125

* Paper version in DSTO-GD-0197, PowerPoint slides here.

---

[1] PowerPoint is a registered trademark of Microsoft Inc for software generating presentation slides.

BFGoodrich Aerospace
Aircraft Integrated Systems

U. S. Navy / BFGoodrich
Integrated Mechanical Diagnostics
HUMS
Overview & Status

LCDR Rick Muldoon
NAVAIR Team Leader
John Gill
Aircraft Integrated Systems
jgill@aisma.bfg.com

IMD HUMS

- *IMD HUMS is a Commercial Operations & Support Saving Initiative (COSSI) to improve helicopter operational readiness and flight safety while slashing maintenance-related costs.*

- *The U. S. Navy (USN) has partnered with BFGoodrich to field this military/commercial "dual use" HUMS.*

2

Gill/Muldoon - 1

IMD HUMS

- **Overview**
  - Program Status / Concept of Operations
  - System Functions
- **Major Airborne Components**
  - Primary LRUs
  - Sensors & IO
- **Selected Functionality**
  - Mechanical Diagnostics
  - Rotor Track and Balance
  - Exceedance Monitoring
  - Engine Monitoring
  - Structural Usage
  - Aircrew & Maintainer Interaction
- **Conclusion**

3

IMD HUMS
Current Status

- **Critical Design Review - Complete June 98**
- **COTS Demo / Risk Mitigation Complete**
  - CH-53E & SH-60F
- **DT Commences - April 99**
  - CH-53E
  - SH-60B
- **OPEVAL - Oct 99**
  - 5 CH-53E (HMT-302) / 5 SH-60B (2@HSL-40, 3@ HSL-41)
- **Limited Rate Production Decision - Oct 99**
  - 6 CH-53Es / Lease for 200+ legacy H-60s
- **Full Rate Production Decision - March 00**
  - All H-53Es / CH-60 / SH-60R

4

Gill/Muldoon - 2

IMD HUMS
STAGE I Sites

Prototype Inventory
Pax River   - 1 CH-53E, 1 SH-60B
New River   - 5 CH-53E
Mayport   - 2 SH-60B
North Island - 3 SH-60B

NAS Pax River MD
(NRWTS)

MCAS New River NC
(HMT-302)

NAS North Island CA
(HSL- 41)

NAS Mayport FL
(HSL-40)

5

IMD HUMS
Concept of Operations

IMD-NALCOMIS
Hardware/Software

Up-line
data to IDE

Flight Data / Regime Data

Reports

PCMCIA

Pre-Flight Data / Post Flight Debrief	Generate VIDS/MAFs/NAVFLIRs	**Internal Users**
	Make Electronic Logbook Entries	Maintenance Control
		QA
	Maintenance Management	MO / MMCO
BUNO & Crew Specific Info loaded in PCMCIA	Configuration Management	Supervisors / Technicians
	RTB Adjustments & Trending	
	Diagnostic Trending	**External Users**
Weight & Balance Data	Scheduled & Periodic Maint. Interval Adjustments	IMA / NADEP / Depots
		Wings / TYCOMs
Fuel Load	Life Limited Comp. Usage	NAVAIR
	Fatigue Life and Exceedance Tracking	CFA / ISST
Weapons Load	Parts Tracking	OEM

6

Gill/Muldoon - 3

IMD HUMS Overview (System)

Cockpit Display Unit (CDU)

RDC

MPU

PPU

Information Management

Maintenance Reports

Aircraft Signals In

VPU

- ● Accelerometers
- ◉ Existing A/C sensors
- ○ Remote Data Concentrator (RDC)

Analysis

Vibration Acquisition

Flight Data & Results

7

IMD HUMS Overview (Functions)

Airborne System

Ground Base System

IMD-NALCOMIS
Hardware/Software

Aircraft Data Transfer

- • Acquire & Process Data
- • Provide Advisories (if desired)
- • Automates Functional Check Flights
  RT&B & Engine
- • Provides Maintenance Info to Flight-line Troubleshooters & FCF Pilots

- • Pilot Debrief
- • Provides diagnostics/prognostics
- • Identifies maintenance actions
- • NALCOMIS Interface:
  Maintenance Management
  Configuration Management
  Serialized Parts Tracking
- • Interactive RT&B
- • Apply usage
  Structural & Operational

| Open System Architecture | | 8 |

Gill/Muldoon - 4

22

Major Airborne Components

Primary Airborne LRUs

Main Processor Unit
(MPU)

Optical Tracker

Data Transfer Unit
(DTU)

Remote Data
Concentrator (RDC)

10

Gill/Muldoon - 5

SH-60B & CH-53-E LRUs

CH-53E Added Sensors
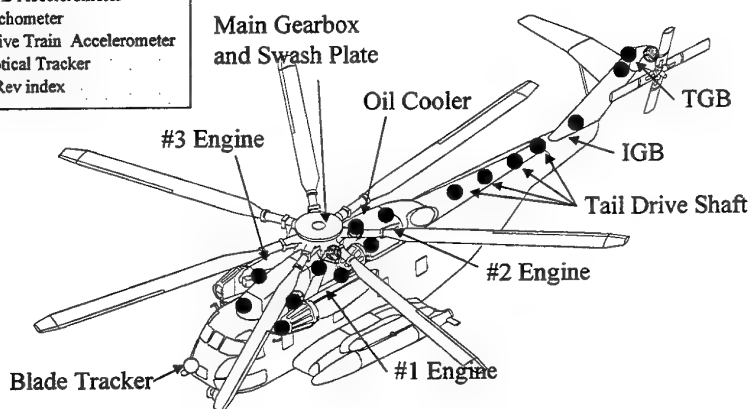
Gill/Muldoon - 6

Generic and Scaleable IO

Signal Type (Inputs unless noted)	H-60B		CH-53E	
	Used	Avail.	Used	Avail.
Discrete Inputs	35	48	63	96
Synchros	0	4	7	8
AC Signal	4	16	12	32
DC Signal	17	32	37	64
Accelerometers	34	36	44	46
Frequency	5	17	7	22
Index	7	8	6	9
MIL-STD-1553	1	1	1	1
RS-422/RS-485 I/O	0	3	1	3
ARINC-429 Inputs	0	13	0	12
Outputs	0	3	0	3
RS-232/RS-422 I/O	0	3	0	3
ARINC-717 (FDR) Out	0	1	0	1

13

IMD HUMS Functionality
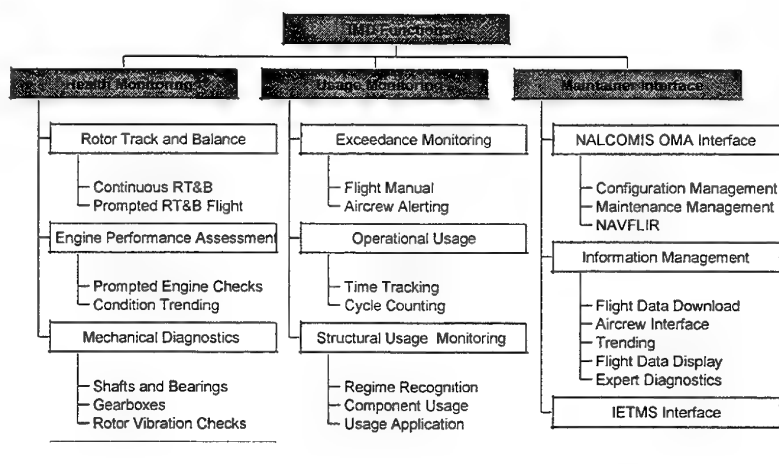
14

Major Functions (Examples)

- **Mechanical Diagnostics**

- **Rotor Track & Balance**

- **Exceedance Monitoring**

- **Engine Monitoring**

- **Structural Usage**

- **Routine Aircrew Interaction**

- **Routine Maintainer Interaction**

15

Mechanical Diagnostics
Functional Flow

Acquisition Prompts

Advisories

MPU

PPU

Determine Component Health

Control Acquisition

VPU

Process Vib. Data
Component Indicators

Acquire Drivetrain Vibration Data

○ 24-30 Drivetrain Accels
● 1 Gearbox Tachometer (H53)
2 Optical Tachos (H60)
Existing Index (H60)

Maintenance Alerts
Diagnostic MAFs

Display/Trend Indicators

Diagnostic Indicators

Raw data
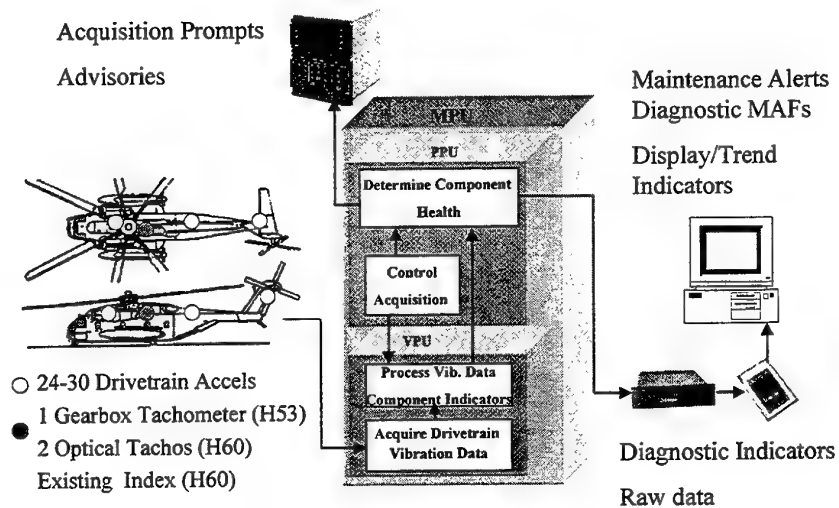
16

Gill/Muldoon - 8

Mechanical Diagnostics

Focus on Gear, Bearing, and Shaft Diagnostics

IN-FLIGHT DATA ANALYSIS
SAFETY OF FLIGHT CALCULATION

GROUND STATION
DATA BASE

AUTOMATED
REPORTS

DOWNLOAD
DIAGNOSTICS
DATA, RESULTS

ONBOARD DISPLAY

- Automatic Data Acquisition
- Pilot-Initiated Acquisition
- Safety of Flight Advisories

- Drivetrain Health
- Component Health
- Component Analysis
- Analysis Tools

17

RT&B Functional

Normally Background
Prompted FCF
   (5) 15 sec acquisitions
Balance Solutions

RT&B MAFs

Balance Solutions

Safety Check For
Incorrect Adjustments

Predict Vibe Levels

Trend Vibrations

MPU

PPU

On-board Balance
Solution

Control
Acquisition

VPU

Calculate
N/Rev and Phase

Vibration & Track
Acquisition

N/Rev Vibe
& Track data

- 8 Accelerometers
- 2 Index sensors
- 1 Optical Tracker

Reduces No. of FCFs / Reduces Average Vibration Level / Eliminates Need for VATS   18

Gill/Muldoon - 9

Exceedance Monitoring Overview

- **Exceedance Monitoring Function**
  - Incorporates NATOPS/maintenance manual limits and time-related thresholds
  - Annunciated only if no other pilot indication is available and Pilot Action is required
  - Exceedance summaries available on OBS/GBS
- **Changes from Present Practices**
  - On-board Crew acknowledgement for certain exceedances (Configurable)
  - Crew review for all exceedances on GBS
  - Automatic MAF request generation if required

19

Engine Monitoring Function

- **Engine Monitoring Function**
  - Usage
  - Limit Exceedance
  - Performance
- **Changes from Present Practices**
  - Automates Data Transfer from OBS to GBS
    - Cycle count, Run Time, Limit Exceedances
  - Automate Selected Power Checks
  - Monitors Vibration
  - Trends Engine Performance

20

Gill/Muldoon - 10

Regime Recognition/Usage Monitoring
Current Implementation

Regime Recognition/Usage Monitoring
Regimes
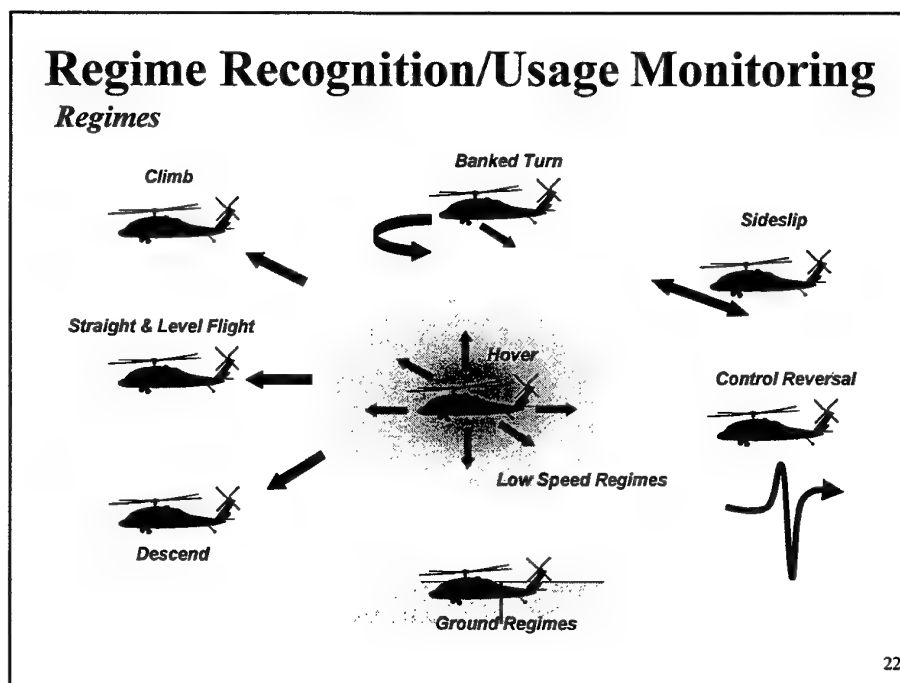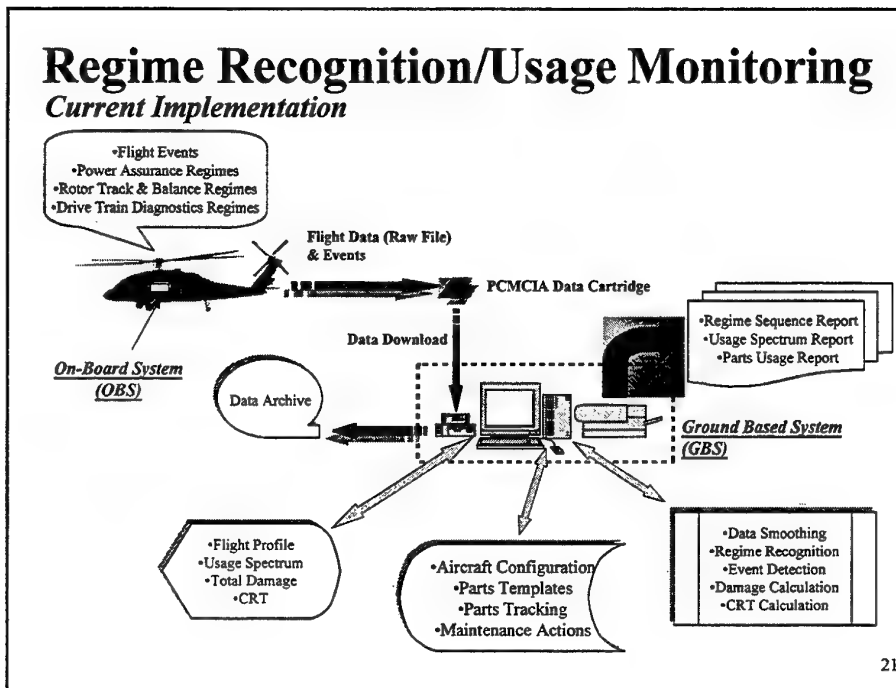
Regime Recognition/Usage Monitoring

Generic Approach

Flight load data are taken on the ground, at three altitudes and at three weights	Each gross weight-altitude combination makes up one part of the core set
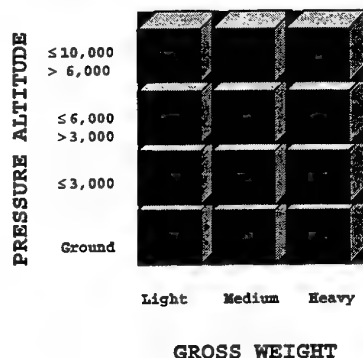
For example;
- One set of regimes for each gross weight - altitude combination (total of 12 core sets).
- Each core set can have the following subset options:
  - level flight, climbs, turns,
  - partial power descents, autorotations,
  - steady heading sideslips,
  - pull-ups, etc.
- Time in each regime relates directly to flight loads used to decrement finite life.
- Ambiguities resolved in conservative way -
  - favor most damaging regime in question

Regime Recognition/Usage Monitoring

Results

Gill/Muldoon - 12

Routine Aircrew Interaction

Select IMD System
- Power Checks
- RTB Checks
- Manual Data Capture
- Status Report
- Advisories (if desired)

Debrief reports

Maintenance Reports

Flight Data & Results

Information Vice Data!!

25

Routine Aircrew GSS Interaction

- **Aircrew Debrief**
- **Acknowledge and Comment**
- **Interface to NALCOMIS**
- **Card Initialization**

26

Gill/Muldoon - 13

Routine Maintainer Interaction

Rotor Track and Balance on CDU

Flight-line Troubleshooting

Data download

Interactive Electronic Technical manuals

NALCOMIS Maintenance Reports
- Aircraft Daily Status Report
- Work Center Work Load Report
- Aircraft/Equipment Work Load Report
- Aircraft Phase Inspection Report
- Aircraft Material Status Report
- Outstanding Requisition –
  Aircraft Material Status Report
- Material Control Register Report
- Inspections by TEC Report
- Scheduled Inspection Report
- Phase Inspection MRC Report
- Special/Conditional Inspection MRC Report

IMD Calculations
- **Regime recognition**
- **Usage Algorithms**
- **Diagnostics**

Rotor track and balance
Troubleshooting
Interactive Diagnostics
Power assurance review
Results viewed on GUI window
Drill down to details

27

Example of Routine Maintainer GSS Interaction

NATOPS T700 Engine Performance

1st HIT Baseline
Engine Wash
3rd HIT Baseline
1st HIT Limit
2nd HIT Baseline
3rd HIT Limit
2nd HIT Limit

Hit Pass
HIT Baseline
HIT Limit
Set Baseline
HIT Fail
TFM Pass
TFM Fail

Date (or Engine Hours)

28

Gill/Muldoon - 14

Fleet Implementation Issues
(A Sample)

- **Implementation planning**
  - Installations / Training / Support / Incremental Implementation of Functions
  - Use of Fleet Advisory Committee
- **Policy & procedure roadblocks - maintenance re-engineering**
  - Total asset visibility during all levels of maintenance
- **Logistics necessary for stage I & II**
  - "O" to Contractor "D"
  - NALCOMIS Optimized OMA installations & Training
  - Publication updates....
- **Anomaly adjudication process**
  - i.e. diagnostic alarms when traditional indicators show no problem
- **Supply for squadron IMD equipped aircraft**
- **Human Factors Engineering - user interface assessments**
- **Capturing benefits**
- **Dealing with IMD & Non-IMD equipped acft in one squadron**

29

IMD HUMS FLEET BENEFITS

- **Open System Architecture - Scalable, Portable, & Upgradeable**
- **NALCOMIS Interface**
- **Maintenance Information Vice Engineering Data**
- **Improved ACFT Safety**
- **Improved Mishap Investigation - FDR/CVR**
- **Increased Availability & Reliability**
- **Reduction in Scheduled Maintenance**
- **Rapid Determination of ACFT Status**
- **Reduced O&S Costs**
- **Decreased MMH/FH**
- **Reduced Schedule Component Removal**
- **Component Life Based on Actual Mission Profile Data Vice Assumed**

30

Gill/Muldoon - 15

33

QUESTIONS

31

Gill/Muldoon - 16

The Royal Air Force

ROYAL AIR FORCE

Flight Lieutenant
DAVE HORSLEY
B Eng C Eng MIEE RAF

HUMS &
GROUND SUPPORT SYSTEMS
TEAM LEADER

SCOPE

- LOGISTICS SUPPORT SERVICES
- EXPECTATIONS
- PROJECTS
- INTRODUCTION STRATEGY

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
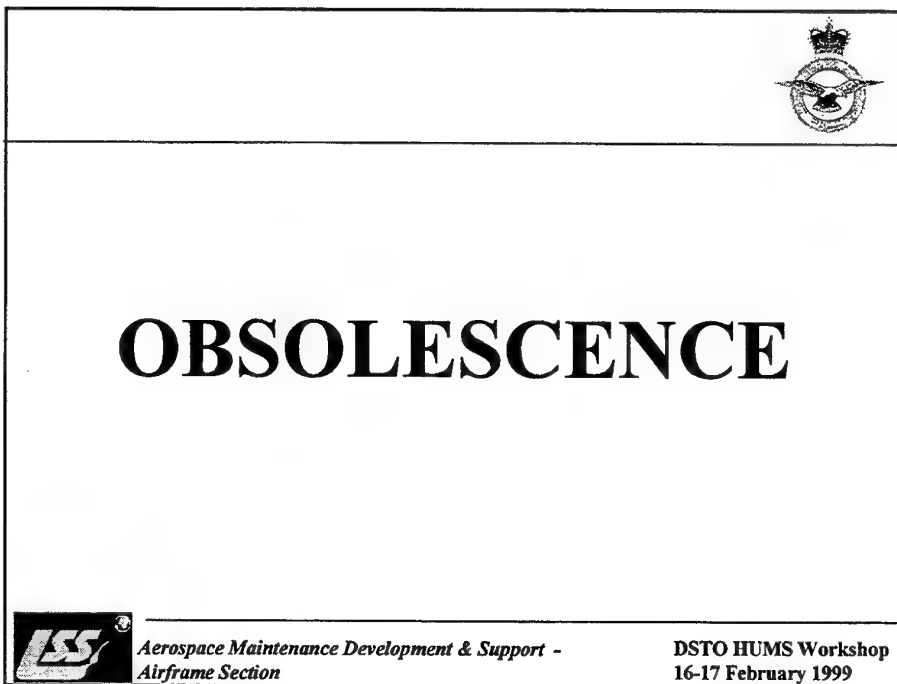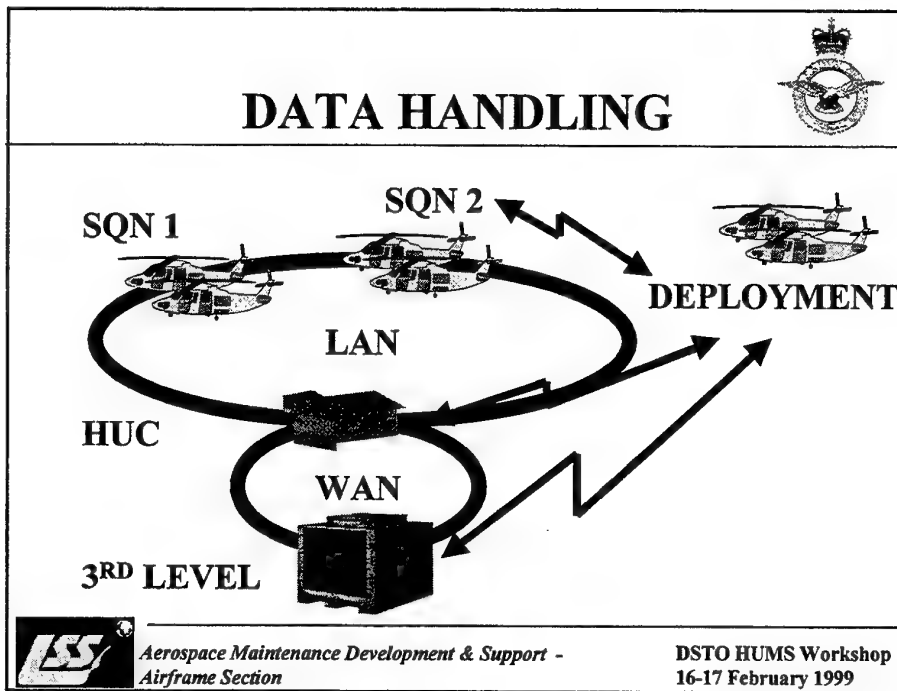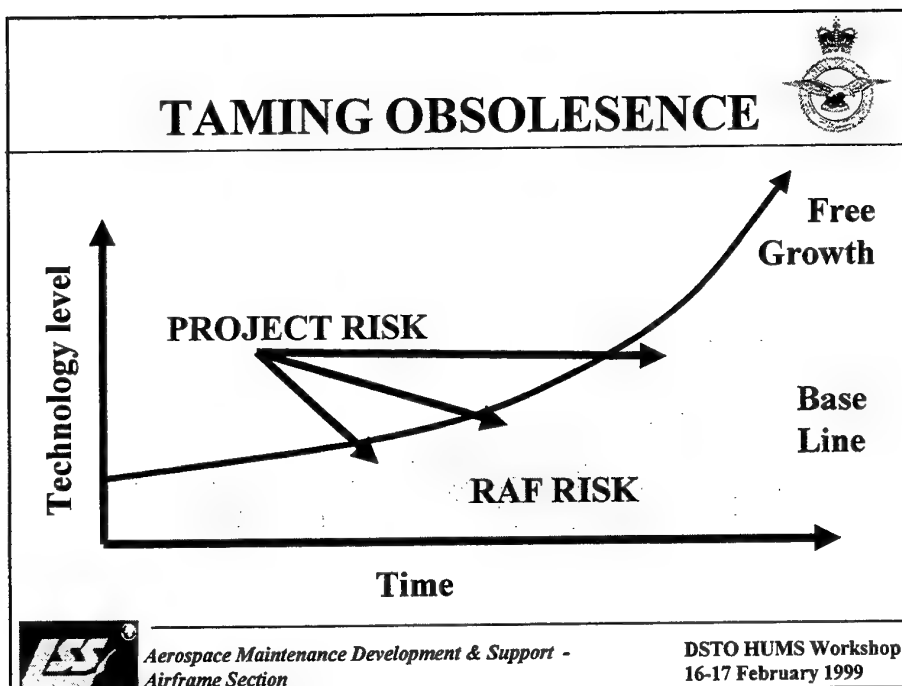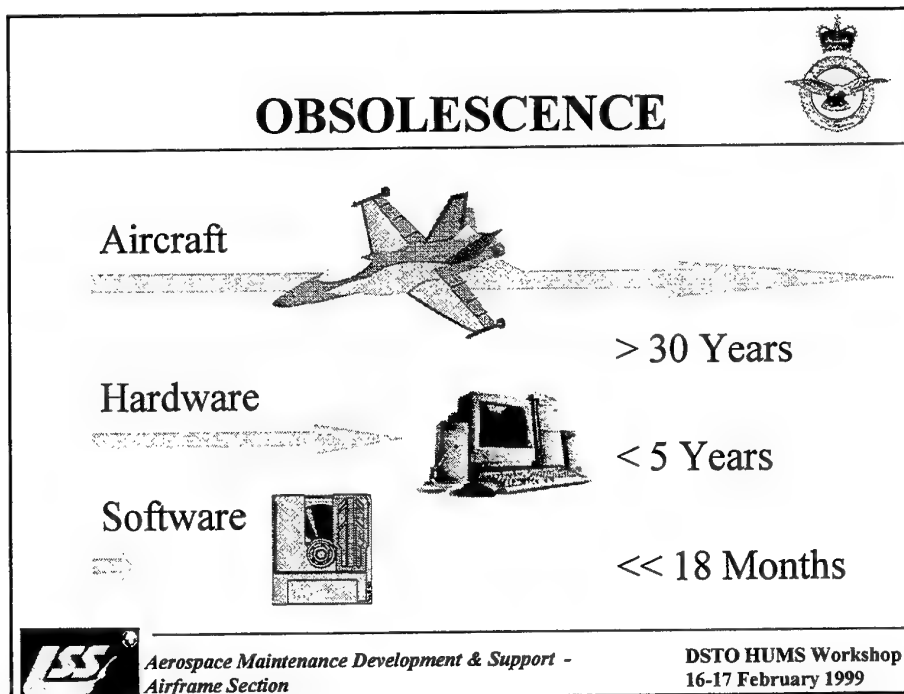**16-17 February 1999**

ENGINEERING CV

RMCS
Cranfield
UNIVERSITY
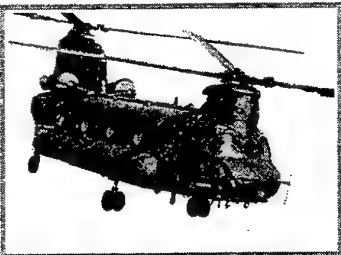
B Eng (Hons)
Electrical Systems

Tornado 2nd line

Chinook 1st line

Engines
3rd line

HUMS & GSS

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 2

LOGISTICS SUPPORT SERVICES
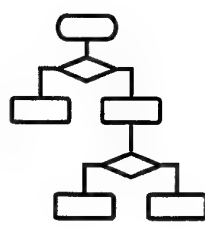
Logistics Computer Centre

Communications Information Systems

Information Data Management

Aerospace Maintenance Development & Support

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

LOGISTICS SUPPORT SERVICES

Aerospace Maintenance Development & Support

Structural Integrity | Aerospace Engineering | Aerospace Projects

Avionics | Test | Schedules | Airframes | Propulsion | Weapons & GSE

Structures | HUMS & GSS | Components

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 3

LOGISTICS SUPPORT SERVICES

```
                    ┌─────────────────────┐
                    │ Aerospace Maintenance│
                    │   Development &      │
                    │     Support          │
                    └─────────────────────┘
              ┌───────────────┼───────────────┐
        ┌──────────┐   ┌──────────┐   ┌──────────┐
        │Structural│   │Aerospace │   │Aerospace │
        │Integrity │   │Engineering│  │ Projects │
        └──────────┘   └──────────┘   └──────────┘
```

| Avionics | Test | Schedules | Airframes | Propulsion | Weapons & GSE |

| Structures | HUMS & GSS | Components |

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

HUMS & GSS TEAM

MISSION

TO ASSIST IN THE EFFICIENT & EFFECTIVE INTRODUCTION TO THE RAF OF HUMS & GROUND SUPPORT SYSTEMS THAT IMPROVE MAINTENANCE DATA COLLECTION & REDUCE MAINTENANCE COSTS, THUS IMPROVING AIRWORTHINESS & MINIMISING THE COST OF OWNERSHIP

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 4

EXPECTATIONS

COST OF OWNERSHIP

AIRWORTHINESS

Aerospace Maintenance Development & Support - Airframe Section

DSTO HUMS Workshop 16-17 February 1999

RAF HUMS PROJECTS

GHUMS

OEM HUMS

Aerospace Maintenance Development & Support - Airframe Section

DSTO HUMS Workshop 16-17 February 1999

Horsley - 5

RAF HUMS PROJECTS

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

INTRODUCTION
STRATEGY

- AIRWORTHINESS

- DATA HANDLING

- OBSOLESENCE

- OEM ACCREDITATION

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 6

AIRWORTHINESS

AIRWORTHINESS

- INSTALLATION IS ENDORSED
- NOT FLIGHT SAFETY CRITICAL

CONFIDENCE

- ALERT CREWS IN-FLIGHT?
- REPAIR OR FLY?
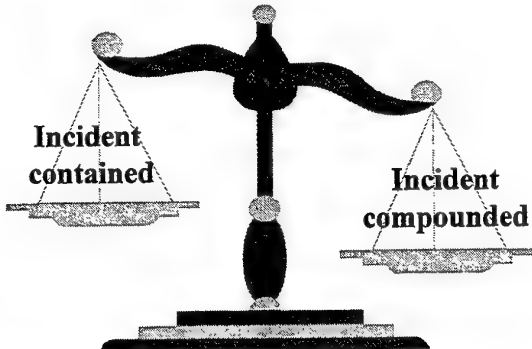
Horsley - 7

AIRWORTHINESS

'TO DISPLAY OR NOT DISPLAY?'
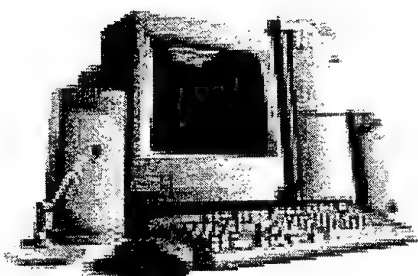
Incident contained

Incident compounded

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

AIRWORTHINESS

GROUND SUPPORT SYSTEM

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 8

AIRWORTHINESS

IN-FLIGHT ALERTS SUPPRESSED

PROCESSED DATA ADVISORY

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

DATA HANDLING

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 9

DATA HANDLING

LOTS OF DATA

$$\neq$$

LOTS OF INFORMATION

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

DATA HANDLING

Front
Line — QUICK ANSWERS

Functions

Health &
Usage Cell — FLEET TRENDS
DATA CUSTODIANS

3rd
Level — DEVELOP NEW TOOLS
MONITOR HUMS EFFICACY

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 10

DATA HANDLING

SQN 1

SQN 2

DEPLOYMENT

LAN

HUC

WAN

3RD LEVEL

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

OBSOLESCENCE

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 11

OBSOLESCENCE

Aircraft

> 30 Years

Hardware

< 5 Years

Software

<< 18 Months

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

TAMING OBSOLESENCE

Technology level

Free
Growth

PROJECT RISK

Base
Line

RAF RISK

Time

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 12

Horsley - 13

OEM ACCREDITATION

Aerospace Maintenance Development & Support - Airframe Section

DSTO HUMS Workshop
16-17 February 1999

SUMMARY

Aerospace Maintenance Development & Support - Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 14

SUMMARY

- HUMS IS COMING

- BENEFITS AND LIMITATIONS

- KEY IS DATA HANDLING

- HARNESS OBSOLESCENCE

- PARTNERSHIPS REQUIRED

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

HUMS AND GSS TEAM

Questions?

Aerospace Maintenance Development & Support -
Airframe Section

DSTO HUMS Workshop
16-17 February 1999

Horsley - 15

The Royal Air Force

Aerospace Maintenance Development & Support - *Airframe Section*	**DSTO HUMS Workshop** **16-17 February 1999**

Horsley - 16

EUROCOPTER H.U.M.S

The Helicopter Manufacturer commitments

EUROCOPTER   HUMS

- Safety and Confidence scope

- End user's needs

- HUMS design principles

- Eurocopter experience

- HUMS module configuration

- Safety &Costs benefits

SAFETY & CONFIDENCE SCOPE
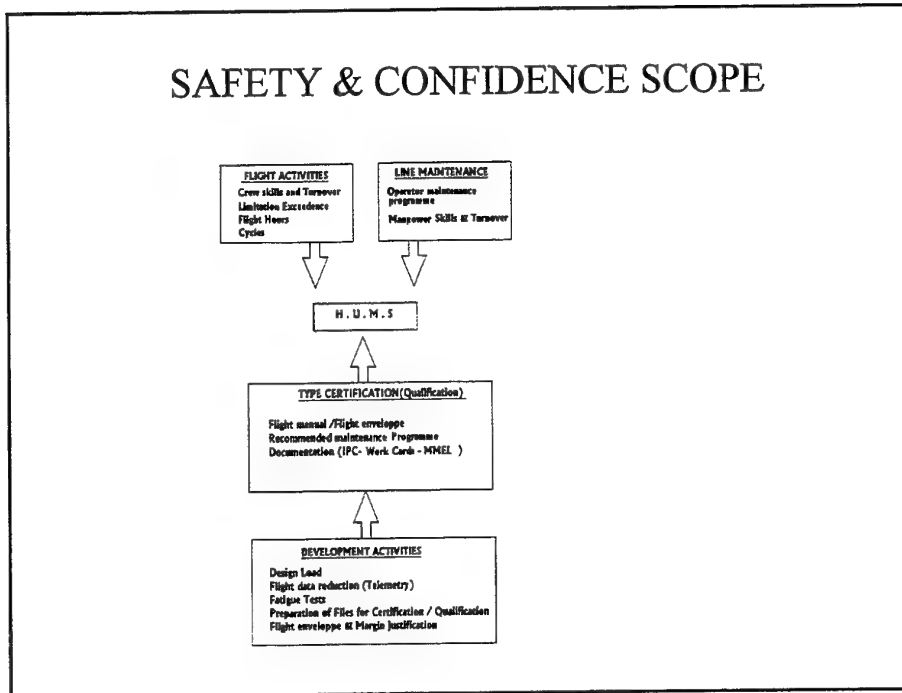
HUMS DESIGN PRINCIPLES (1)

- **<u>Many possible simple functions</u>**
  - Ex: Usage, Health (Vibration airframe+Eng.), RT&B

- **<u>Equipement status</u>**
  - Airborne Kit
  - Ground station computer (Flight Report / Maintenance reports)
  - Ground support equipment (System maintenance)

Lubrano/Feraud - 2

HUMS DESIGN PRINCIPLES (2)

- **<u>System Approach</u>**

- Early integration analysis
- Specifications to be done for each function related to HW & SW
- Modular concept design
- Module development

HUMS MODULE CONFIGURATION (1)

- **<u>Module 1: Usage Functions</u>**
  - **Basic a/c parameters**

- Flight hours counting
- Cycle counting
- Exceedance of limitation
- Power assurance check
- CD rom documentation link (Work cards / MSR)

Lubrano/Feraud - 3

HUMS MODULE CONFIGURATION (2)

- **Module 2: Engine vibration health**
  - An important part of the H/C
    - ➔ Engine manufacturer approval
  - PAC in accordance with MM of the Engine Supplier
  - Functions developed in accordance with the engine Manufacturer experience & its design criteria

- **Module 3: H/C Vibrations**
  - Vibration Status of H/C and its monitored components
  - On board Rotors Track & Balance
  - Link with CD rom documentation

HUMS MODULE CONFIGURATION (3)

- **Module 4: Transmissions(Health)**
  - Drive Shafts (Unbalance / Bearings)
  - Gearboxes
  - Link with CD rom documentation

- **CV/FDR Module**
  - Existing sensors
  - Additional equipment

Lubrano/Feraud - 4

END USER'S NEEDS (1)

- **Basic EC customization**

    - 7000 flying helicopters for more than 1500 customers
    - ⌐ 1500 different customized configurations
    - Yearly flying rate: 2 000 000 hours

- **Actual & contractual Use of the Helicopter**

    - Civil / Military
    - Airworthiness & Operational regulations
        - FAA, JAA, CAA, DGAC, OffShore
    - Specific flight envelope & profile (ex: Logging)
    - Yearly Rate

END USER 'S NEEDS (2)

- **User 's Environment**

- Air & Ground manpower
- Airworthiness organization
- Maintenance facilities (level/PBH)
- Computerized stores & spares management
- Mission preparation systems/fleet management
- Communication network
- Computer policy

END USER 'S NEEDS (3)

- **HUMS Documentation**
- Part of the helicopter documentation
    - HUMS basic complement and enhanced user guide for efficient trouble shouting.
- Available in paper or electronic format.

- **HUMS Training**
- On line maintenance
- GSC&GSE operator
- HUMS administrator

END USER'S NEEDS (4)

- **HUMS Support**

- Controlled service introduction and assistance (HUMS in relation with all a/c aspects)
- Technical assistance (on the job or on call basis)
- Optimum spares avalaibility
- HW & SW cots obsolescence survey
- Continous operational conditions
- Easy & reliable upgrades
- Customized support contract
- Annual user 's conference

Lubrano/Feraud - 6

EUROCOPTER EXPERIENCE (1)

- **Early involvement in design & support**

- **Super Puma & Cougar:**
  - 80 systems fitted
  - Over 100,000 hours flown

- **Upgrades in continuous progress**

- **Available products for all EC helicopters version**

EUROCOPTER EXPERIENCE (2)

- **<u>Safety Enhancement & Cost reduction</u>**

  - You get « both » with HUMS

  - Cost benefit must be calculated with accurate assumptions

  - A certified helicopter is safe
    - ➜ It is safer with HUMS

EUROCOPTER EXPERIENCE (3)

- **COOPERATION**
- H/C manufacturer / Equipment vendor / Users have to win together

- These 3 actors will be actively pushed forward by airworthiness authorities (JAA-CAA), and by new operational requirements.

- Each party has an added value to be identified in order make sure that the job is not done twice.

EUROCOPTER EXPERIENCE (4)

- **Former difficulties**
  - HUMS understanding
  - False Alarm rate
  - Usage data provides "more accuracy"
  - Hardware reliability
  - Software configuration management

- **Current Status**
  - HUMS is running stable
  - Defect reports are managed through our Support centers
  - Improvement of H/C work cards (Trouble shooting+Maint.)
  - Safety cases have proven HUMS added value

Lubrano/Feraud - 8

EUROCOPTER EXPERIENCE (5)

- **HUMS Community**
  - Annual EuroHUMS Conference
  - Working group has defined field of benefits
  - CAA HUMS task force
  - Insurance companies briefing by EC periodically

- **EC HUMS support centers**
  - Specific services have been put in place
    - Hot line, On job training, Tech assist 24h
  - Networks (EC/ End Users - Base to Base)

SAFETY & COST BENEFITS (1)

- **Detected fault cases**

- MGB gear failure
- Tail rotor fitting crack
- Engine / MGB drive shaft unbalance
- MGB bearing advanced wear
- Maintenance error on tail drive shaft

- ➔ **Safety has been increased**

SAFETY & COST BENEFITS (2)

- Former accident status
  - Accident origins are approximately:

    - Pilots: 80%

    - Maintenance: 15%

    - Tech. Issues: 5%

- Each field of accident has the possibility to be reduced by the use of HUMS.

SAFETY & COST BENEFITS (3)

- **Use of HUMS Database**

- Being updated every day

- Pilots & Mechanics behavior and turnover

- H/C historical exceedance data (a/c and LRU)

Lubrano/Feraud - 10

SAFETY AND COST BENEFITS (4)

- **<u>Achieved Cost Reduction</u>**

- Technical Flight reduction
- Ground tests reduction
- Lighter scheduled inspection
- Better vibration status of the Helicopters
    - Crew / Passengers / Equipments
- Customized maintenance for limitation exceedence
- ↘ Cost of overhaul for monitored components
- TBO extension

- ↘ Unscheduled maintenance by 20%

Conclusion

- Since 1993, Eurocopter has tried to offer the best alternative to its customers based on their growing operational requirements

- We have taken into account all economical and technical aspects related to the products offered to our customers. So far, the ROI has been confirmed by users as follow:

- **Heavy helicopters**
    - Civil: 4 to 5 years   /   Military: 7 to 10 years
- **Medium/Light Helicopters**
    - Civil: Less than 3 years / Military: 3 to 5 years.

DSTO

MACHINE DYNAMICS

Brian Rebbechi and Albert Wong
AMRL

Helicopter HUMS Workshop

AMRL Fishermens Bend Melbourne, Australia

16th - 17th February 1999

DSTO

Machine Dynamics Tasks

Task	Title	Task Manager
DST98/164	Advanced Transmission Diagnostics ■ Algorithm development ■ Psycho-acoustics (ISVR) ■ Bearing fault detection (COE) ■ Smart bearing ■ Acoustic detection (Melb Uni)	Albert Wong
AIR97/090	Propulsion System Vibration Analysis – RAAF ■ AMAD ■ TF30	Brian Rebbechi
NAV98/094	Vibration Monitoring of Navy Helicopters ■ Hardwiring of Seahawk and Sea King fleets	David Blunt
NAV98/267	Active Vibration Control of Propulsion Systems ■ Concept demonstrator	Brian Rebbechi
COM98/245	Eurocopter Seeded Fault Analyses – Commercial ■ Consultancy	Albert Wong

Rebbechi - 1

DSTO

NAV
(active
control)

acoustic
techniques
Melb Uni

RR

NAV
(Seahawk,
Sea King)

TF30
model

DST

AIR (AMAD, TF30,
T56)

Non-linear
rotordynamics model
COE

Advanced bearing
diagnostic methods
COE

DSTO

AD- Hoc Investigations

F/A-18 AMAD Gearbox

T56 Turbine Blades

Rebbechi - 2
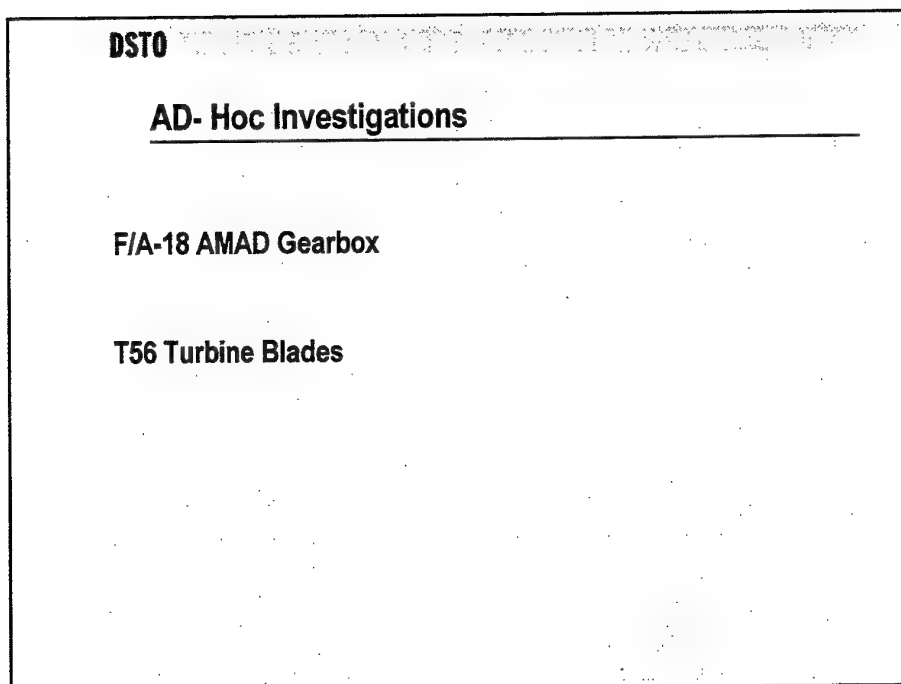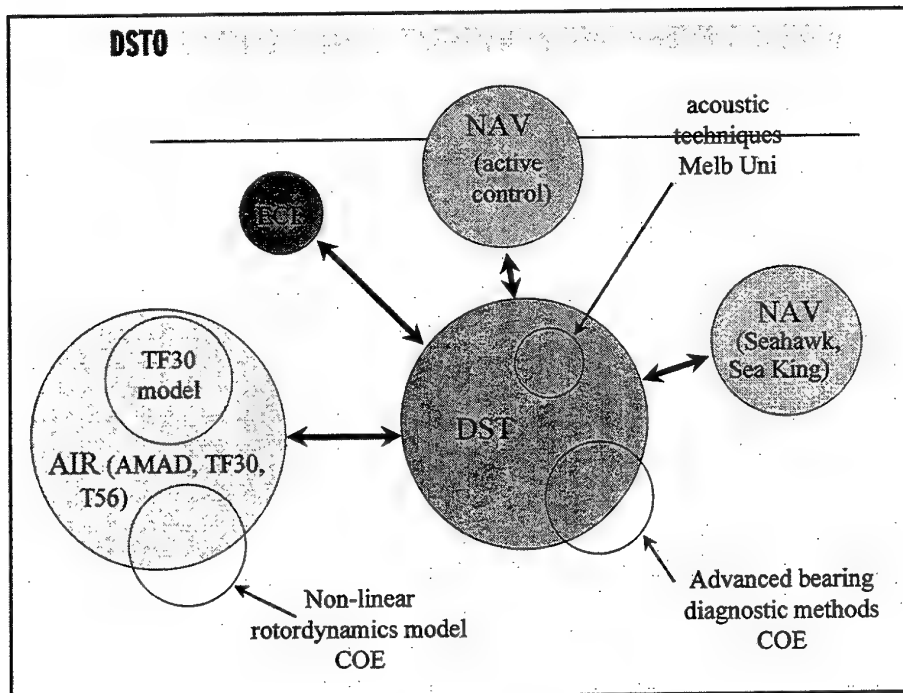
DSTO

F/A- 18 AMAD GEARBOX
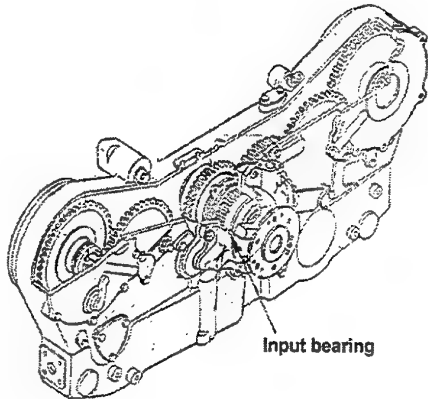
1. Failures of the input bearing have resulted in two in-flight fires.

2. The second fire caused substantial airframe damage which required overeats repair.

Input bearing

DSTO

Initial Assessment of Problem

1. Very high vibration levels, largely as a result of unblanace due to shaft clearances and proximity of drivetrain to critical speed

2. Alleviation of problem by assessing all aircraft, and developing a procedure to reduce vibration by shaft rotation

RUN UP - A/C 116 LHS AMAD

Rebbechi - 3
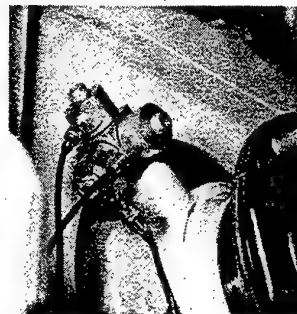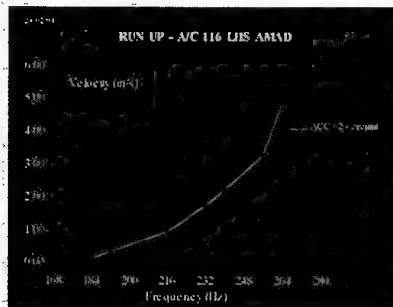
DSTO

Dynamic Load Measurement

Dynamic bearing load measurement using strain gages confirmed estimates of high bearing load. Measured values in excess of 500 lbf (Design 130 lbf) which will have life of less than 400 hrs at 100% power
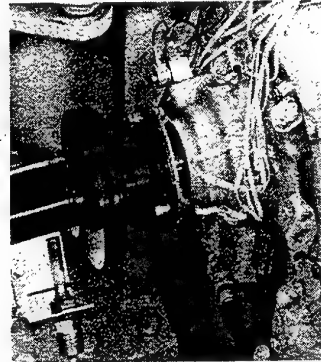
DSTO F/A 18 AMAD Gearbox Test Rig
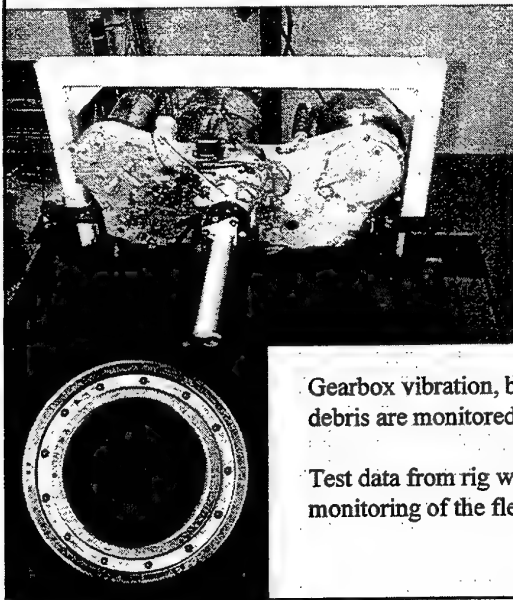
Design changes introduced from June 2000 to June 2002 (Bigger input bearing)

AIM: To fail bearing under service conditions. ~500lbf radial unbalance load applied.

Gearbox vibration, bearing cage speed and wear debris are monitored.

Test data from rig will complement existing vibration monitoring of the fleet.

Rebbechi - 4

T56-A-7B Turbine Blades

Investigating possible natural frequency excitation leading to failure

Frequency screening of new blades

QANTAS will take over screening

T56-A-7B Turbine Blades

Frequency screening of new blades
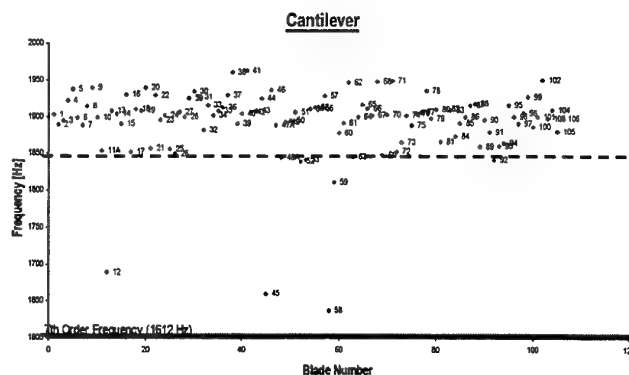
Rebbechi - 5

DSTO

RAN Hard Wiring for Sea King and Seahawk

Chadwick - Helmuth Track and Balance

AMRL diagnostics of main, intermediate and Tail rotor

DSTO

Ruggedised Portable PC System
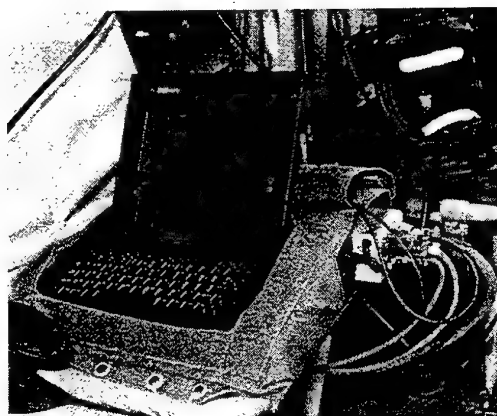
Fieldworks FW7500 PC (75MHz 486)

Custom built signal conditioning card (6 accelerometer + 2 tacho channels)

Anti-aliasing filter card

A-to-D converter card

Connector interface

Rebbechi - 6

DSTO

RAAF Aircraft Diagnostics

DSTO
TF30 Vibration analysis system

Multi channel data acquisition

   – realises $200k fuel
     saving per year

Advanced Diagnostics

   – Nyquist and bode
     using engine tachos
   – Cascade analysis

File : D:\AMBERLEY\TROUBL~1\PROGS\C1N1_3.DAT
CASCADE PLOT

Rebbechi - 7
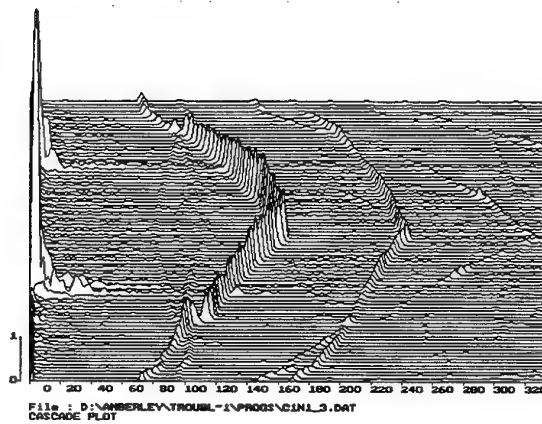
DSTO

3D finite element model

Have constructed 3D FE rotordynamics model

Used to simulate structural faults and refine fault predictions
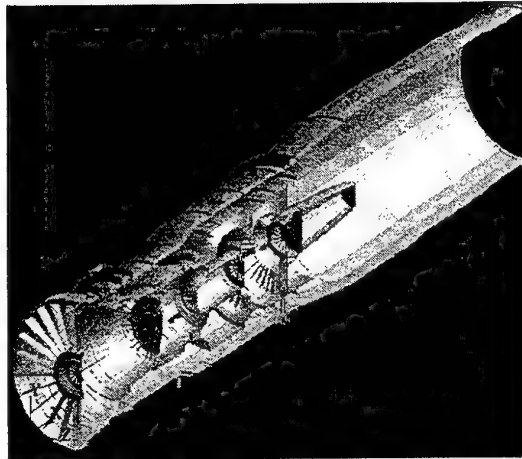
DSTO

Rotor-dynamic modelling

- From a measured run-up curve give prediction of unbalance distribution and structural fault degradation
- Uses Finite Element mathematical model of TF30 and optimisation algorithm
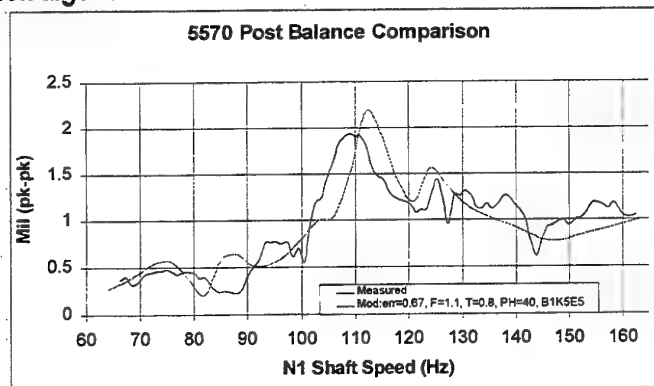
Rebbechi - 8

DSTO

Background R&D

DSTO

Helicopter Transmission Test Facility
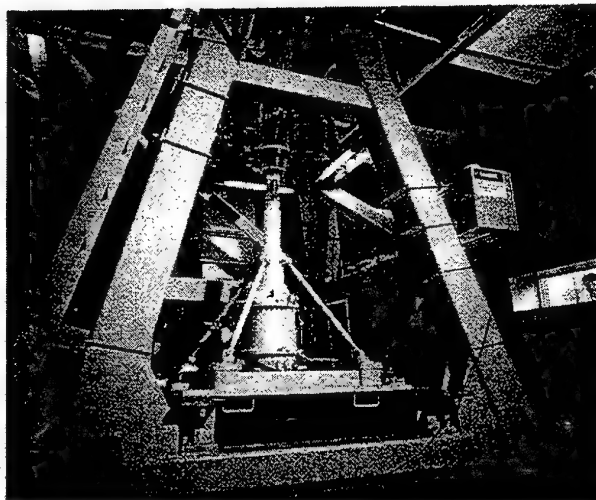
DSTO

Planet Separation Techniques

DSTO

SMART BEARINGS
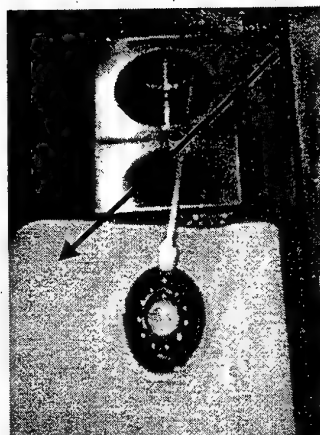
PVDF Piezoelectric film (between bearing outer race and housing) senses vibration

Will ultimately trigger alarm once vibration amplitude exceeds threshold

Rebbechi - 10

Time Signal of Synchronous Average

Tooth Crack

Rebbechi - 11

Kurtosis vs run time

Residual Envelope Kurtosis

10 kW

45 kW

5 kW

33 kW
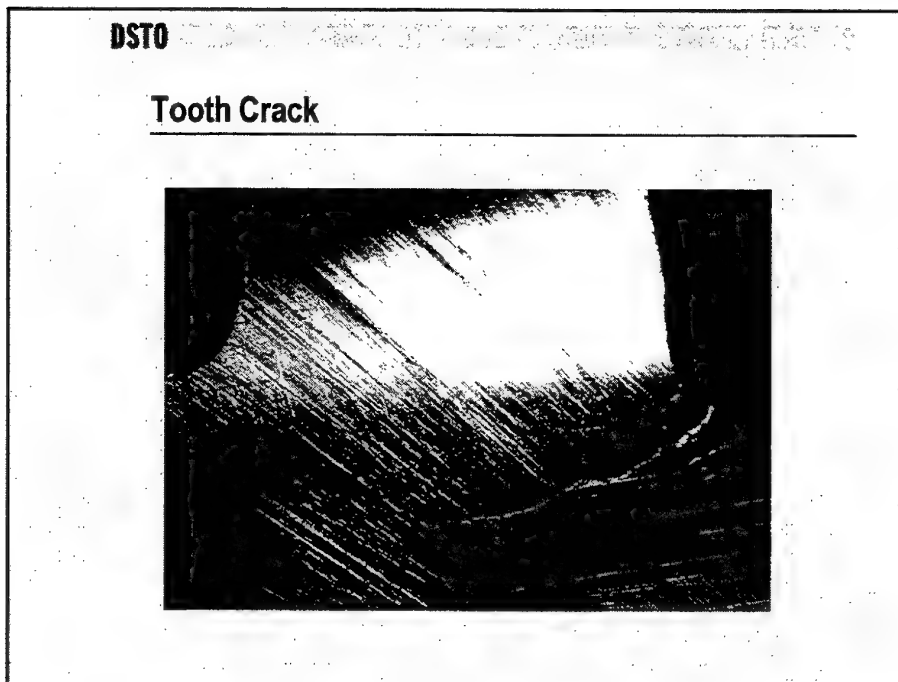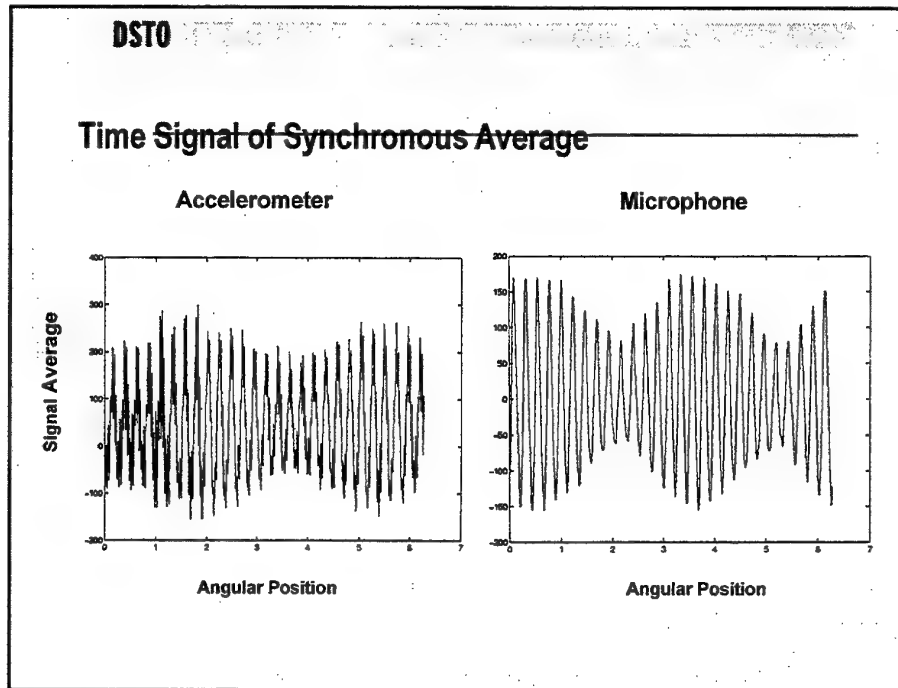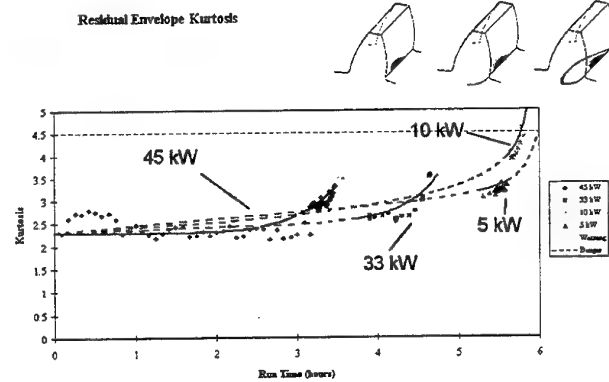
Future Directions

Primary role is to Support ADF

R&D Development of diagnostic techniques

International collaboration USN, UK

Rebbechi - 12

J. Rosinski
Design Unit
Gear Technology Centre
Newcastle University (UK)

Gear Noise and Vibration Research at National Gear Technology Centre

ORGANISATION & FACILITIES

Self-funding research, development and design group in the field of mechanical power transmission, working for industry and government.

Founded: 1970
Staffing: 19 full time staff: 10 Engineers, 7 Technicians, 2 Secretaries.

Rosinski - 1

WORKSHOPS

Well equipped mechanical and electronics workshops for the manufacture of test rigs and instrumentation.

LABORATORIES

- **Gear Noise and Vibration Laboratory with 8 MW back to back test facility.**
- **Gearbox Test Laboratory for parallel axis and worm gearboxes.**
- **Gear Fatigue Test Laboratory with 8 test back-to-back rigs of 75mm and 160 mm centres and up to 1.6MW power.   Metallurgical & Materials Laboratories including facilities for X-ray diffraction, atomic force microscopy etc.**
- **National Gear Metrology Laboratory - the UK national standards laboratory for gear metrology.**

Rosinski - 2

EXPERTISE

- Gear, gearbox and transmission system design and development, particularly for low noise and high strength
- Gears system dynamic analysis (experimental and theoretical)
- Special measurement and data analysis systems for mechanical drives
- Gear material surface and bending fatigue strength, metallurgy and heat treatment
- Gear noise and vibration measurement and analysis
- Gear manufacture and metrology
- Gear Stress analysis including full 3-D FE based elastic mesh analysis
- Failure investigation and analysis and on-site load, stress and vibration analysis of mechanical systems

AREAS OF WORK

The Design Unit has experience of design, analysis and troubleshooting in mechanical transmission systems for:

- marine propulsion, including naval gearboxes
- industrial drives including mining, quarrying, steel plant and chemical plant applications
- rail traction drives, AC and DC, EMU's, locomotives and light rail
- automotive gearboxes for cars, off-road vehicles, buses, HGV's and heavy quarry equipment
- control and servo drives for machine tools, printing machinery and materials handling.

RESEARCH

The Design Unit is engaged in fundamental research in the following areas of gear technology:

- gear stress analysis
- gear noise and vibration
- gear material fatigue strength enhancement
- gear system dynamics
- gear grinding
- gear metrology

SERVICE FOR INDUSTRY

A dedicated team of engineers provide rapid on-site technical assistance in solving industrial problems. Work is typically undertaken not only in the UK but anywhere in the World.

Rosinski - 4
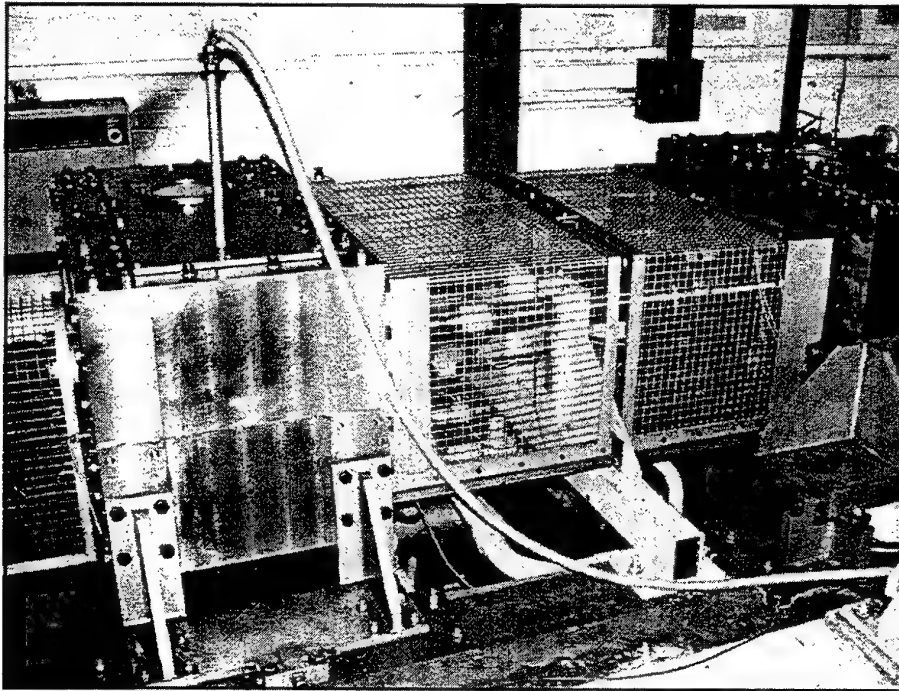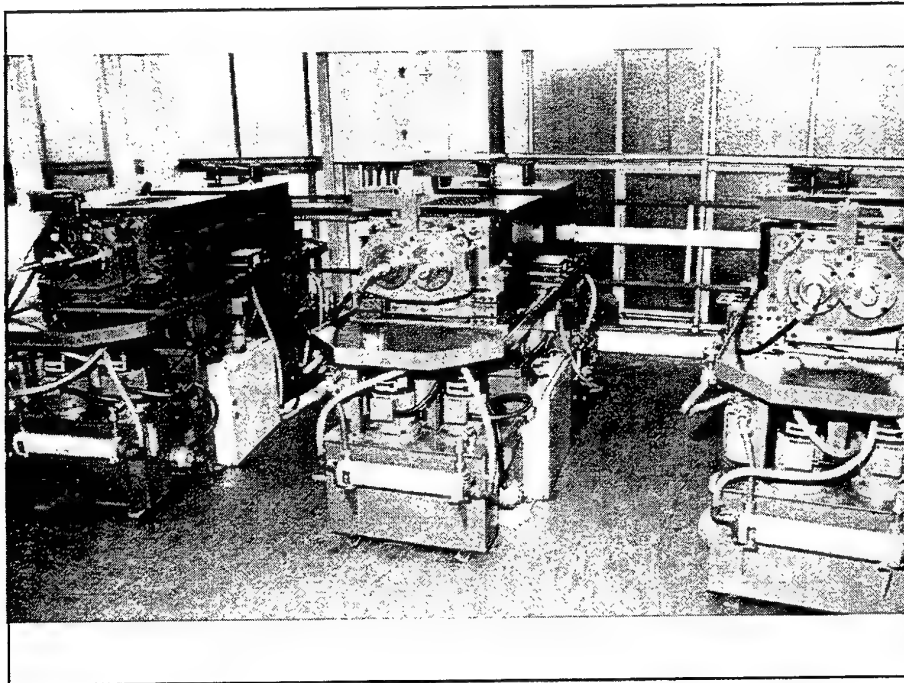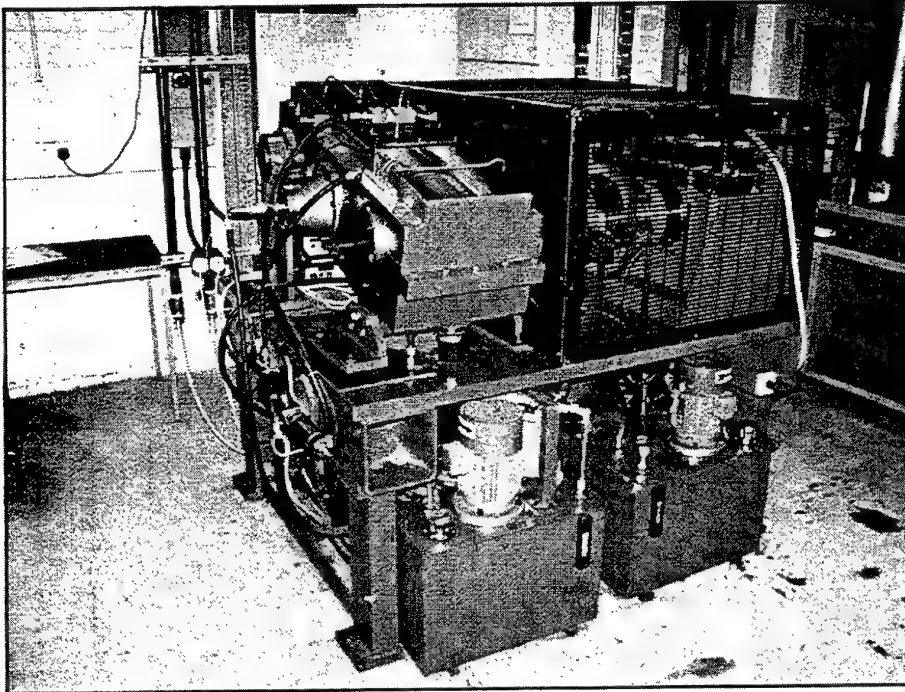
Rosinski - 5

Rosinski - 6

SPECIAL INSTRUMENTATION

- •Telemetry Systems
- •Miniature Slip Ring Instrumentation
- •Unattended Data Loggers
- •Electronic Gear Alignment Instrumentation
- •Portable Gear Inspection Instruments
- •Miniature Strain Gauge Amplifiers
- •Dedicated Computer Based DSP - Built Inside Gear Elements
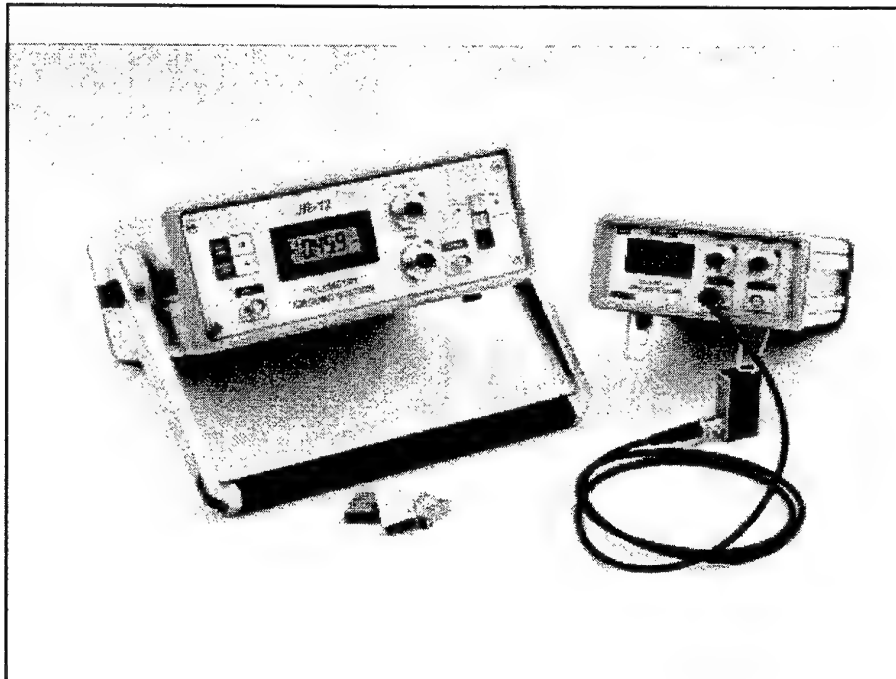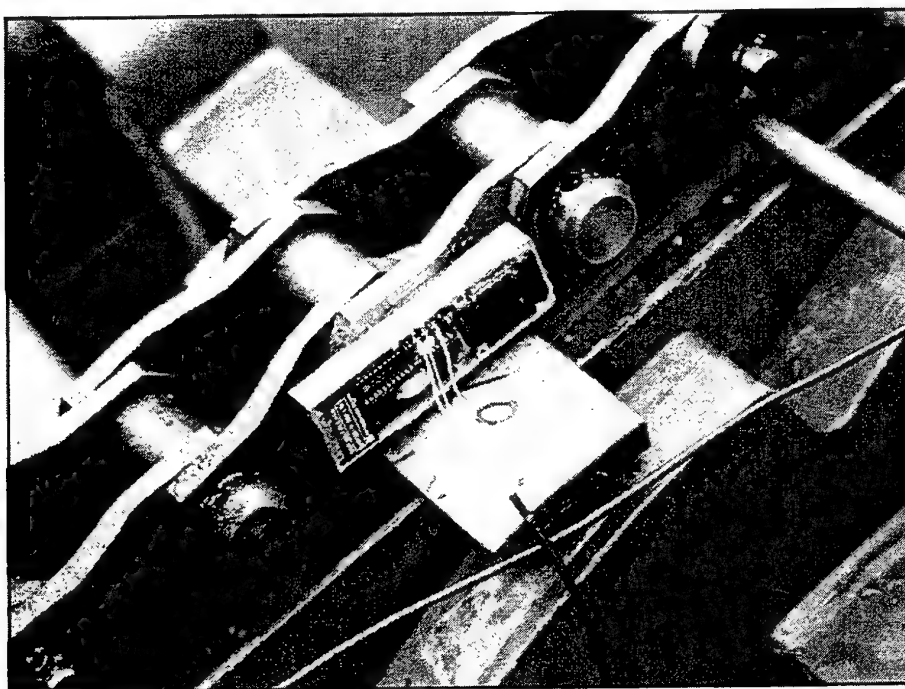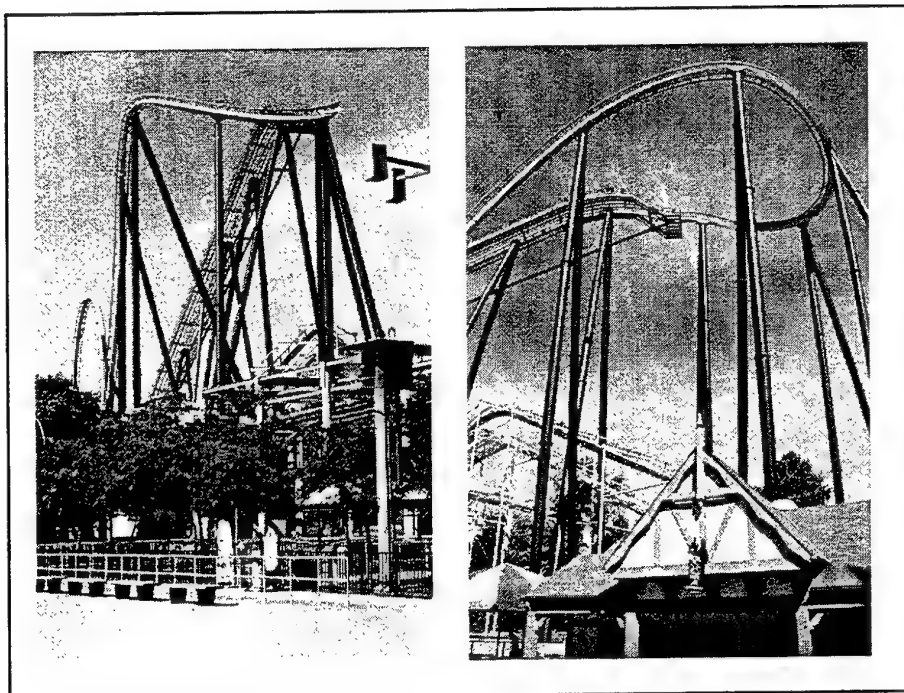
Rosinski - 7

Rosinski - 8
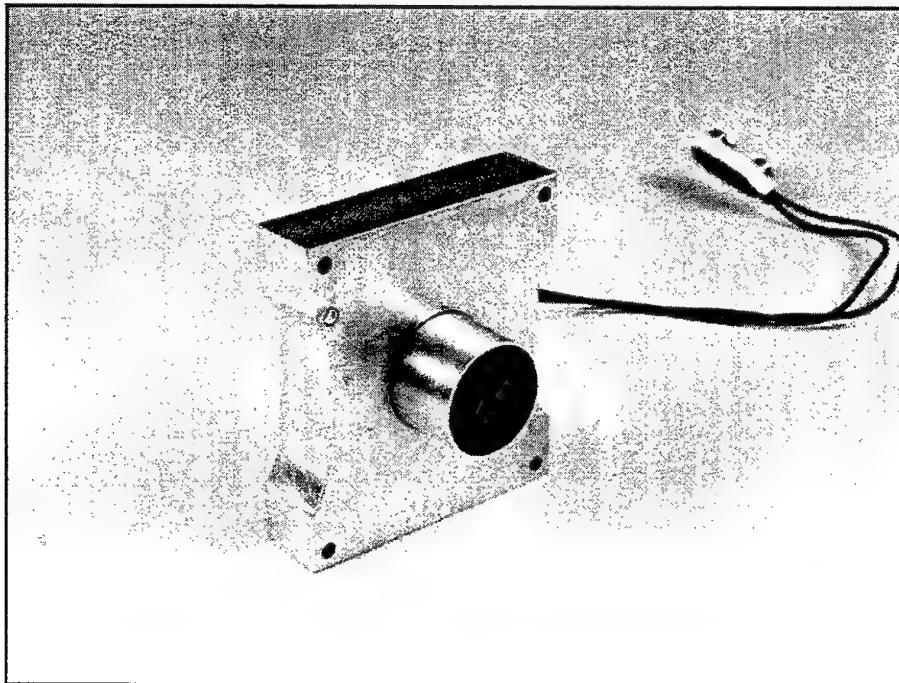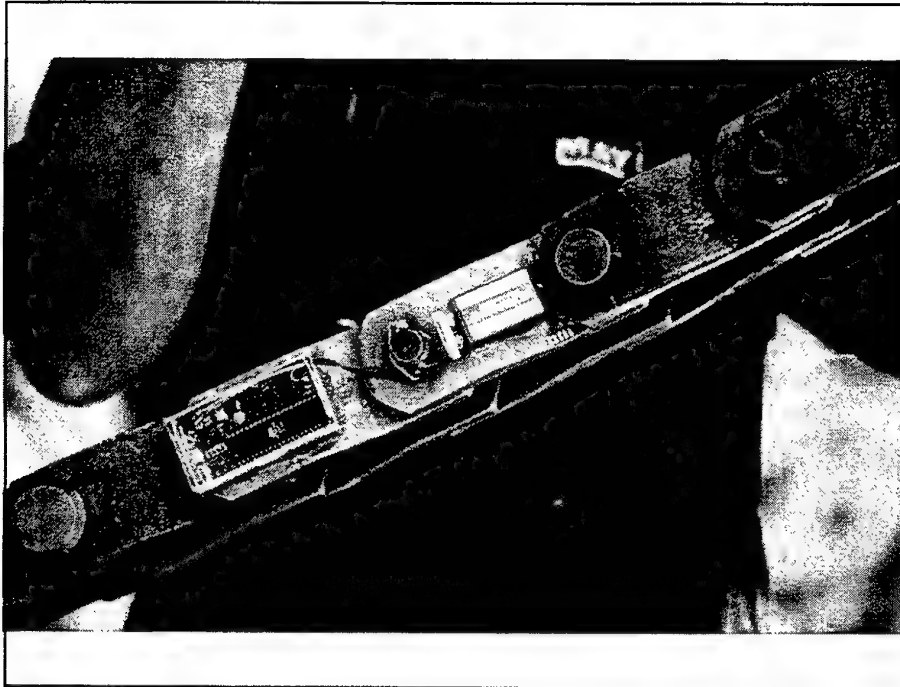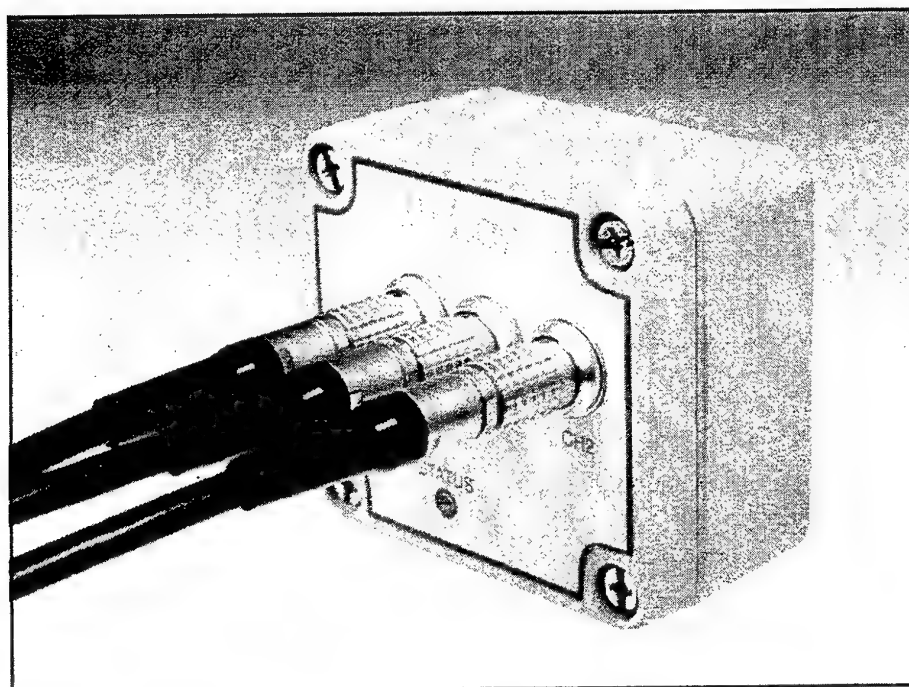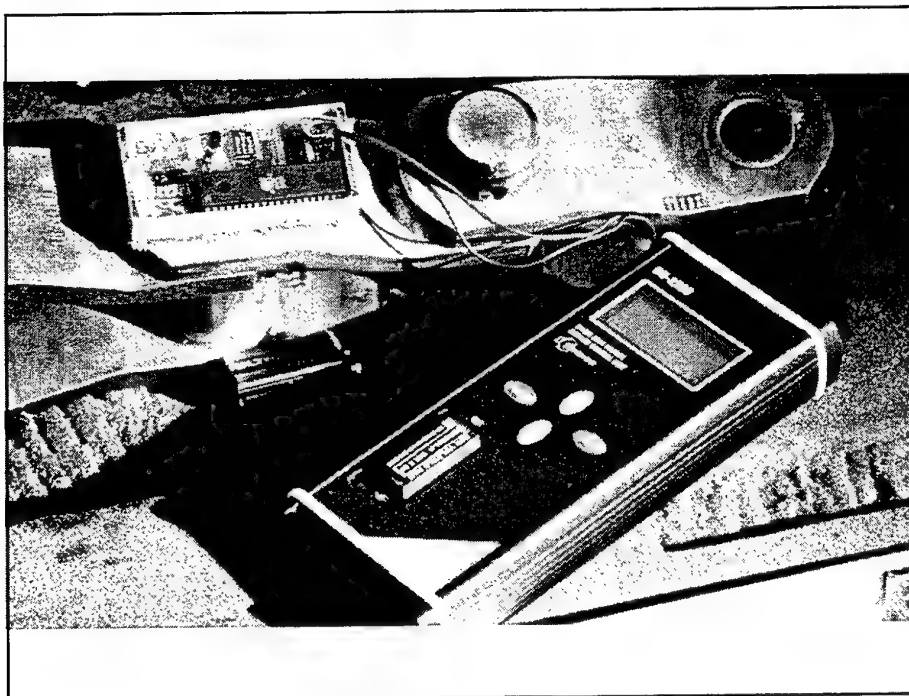
Rosinski - 9

Rosinski - 10
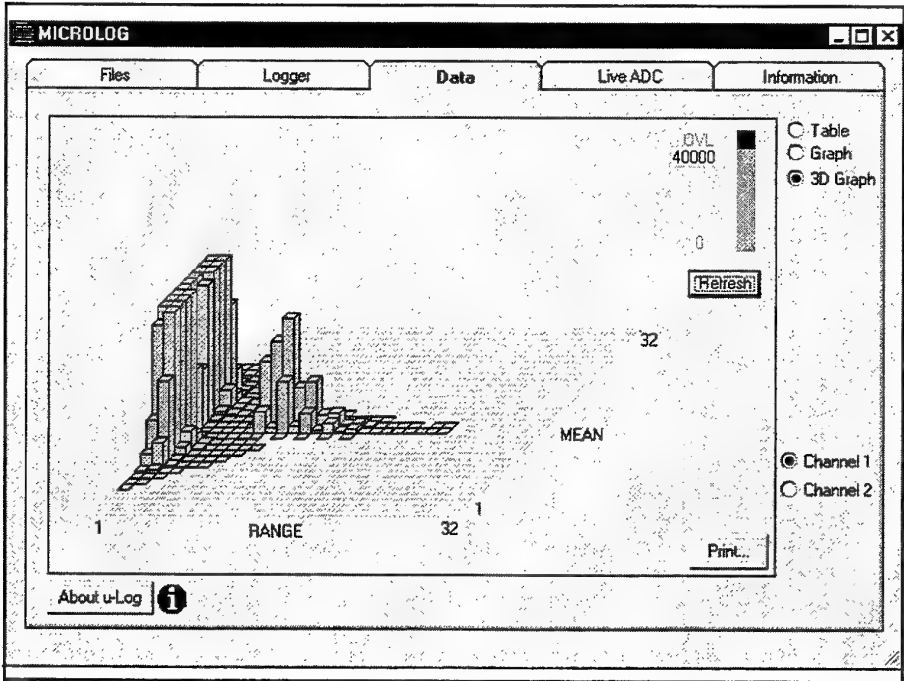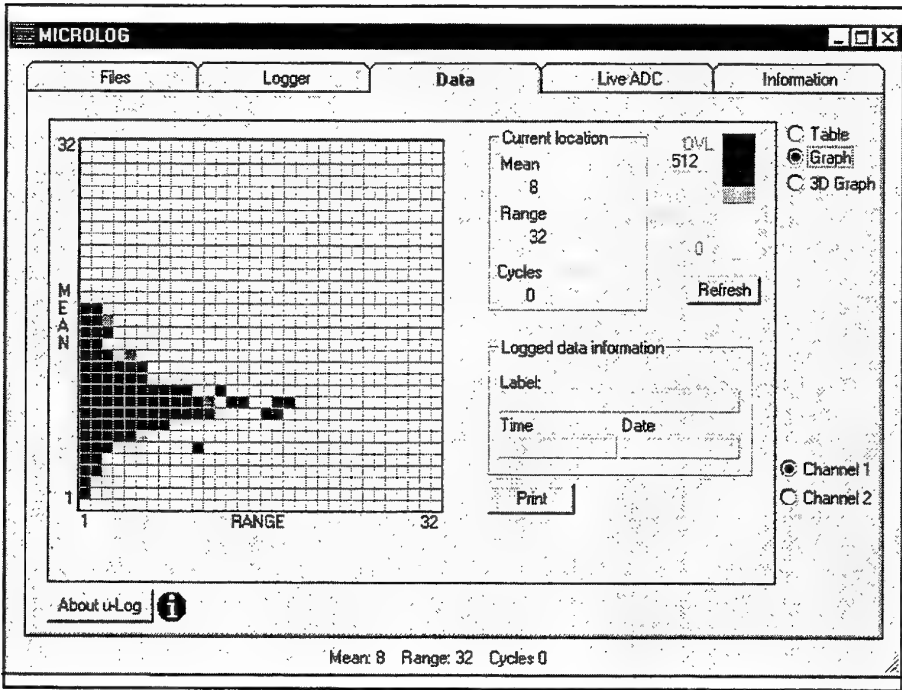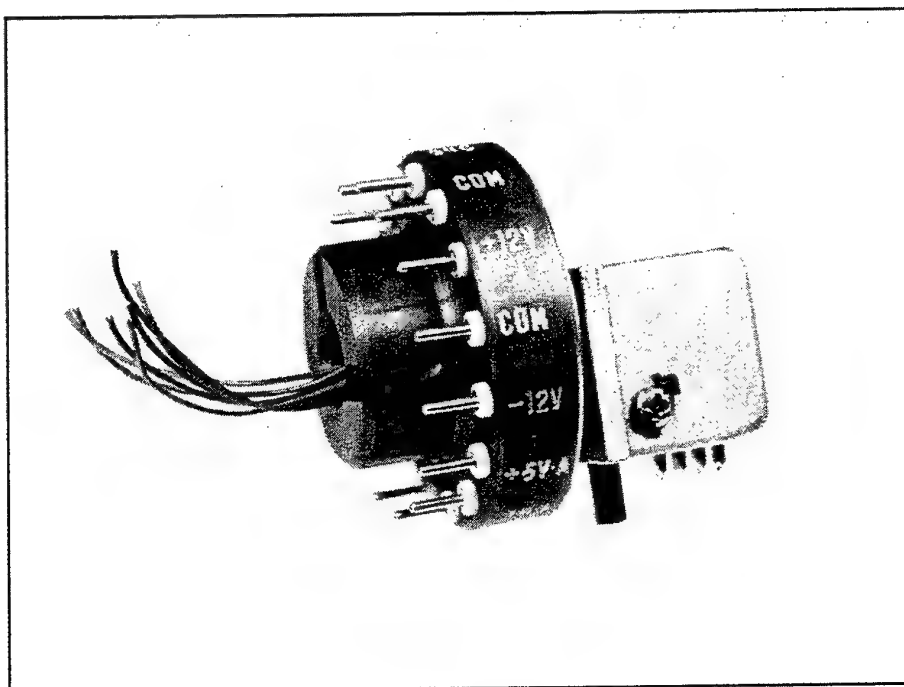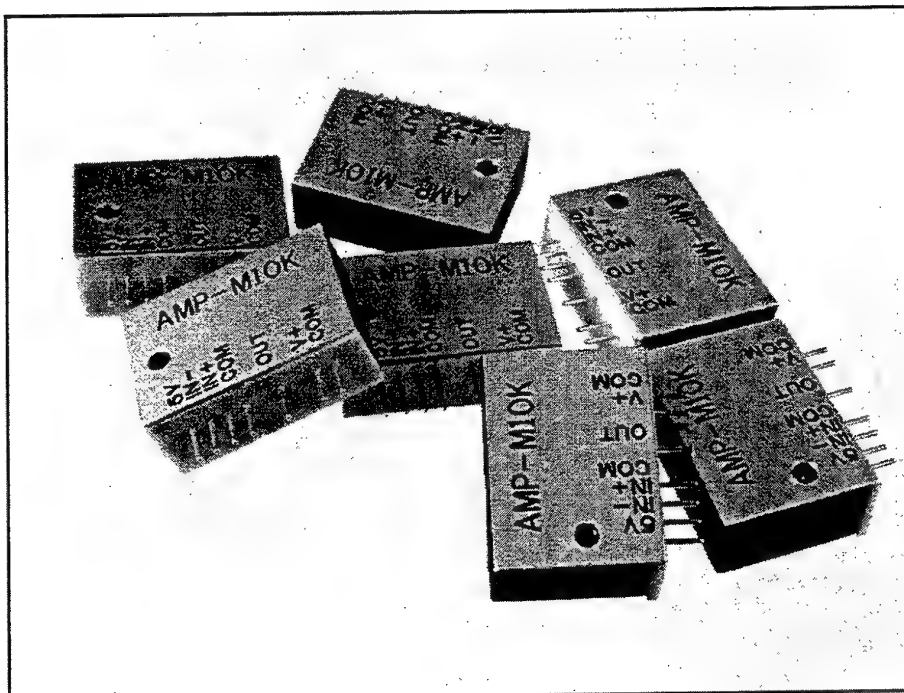
Rosinski - 11

Rosinski - 12

IN - SERVICE GEAR ALIGNMENT
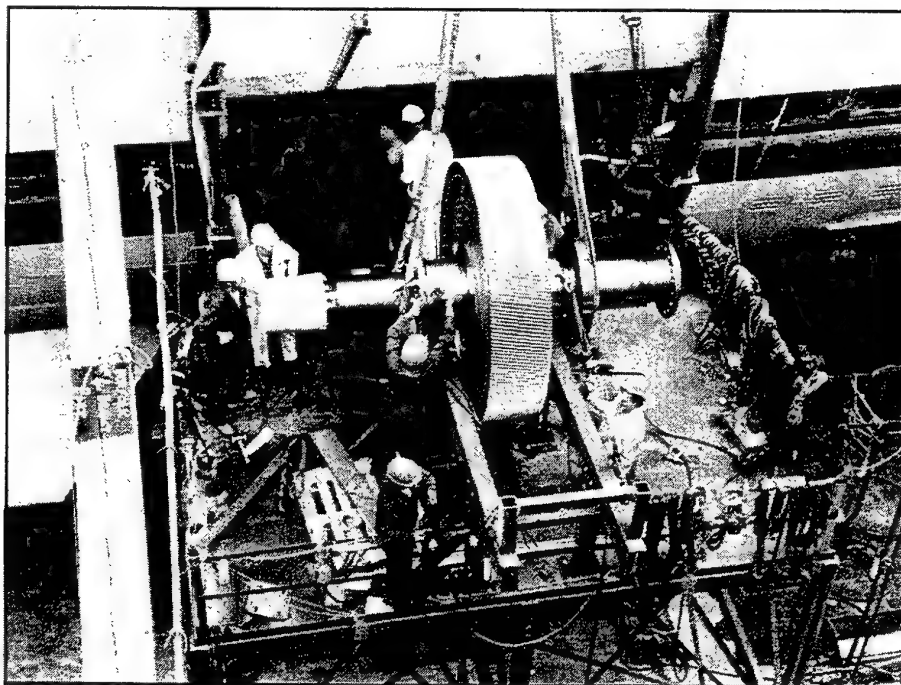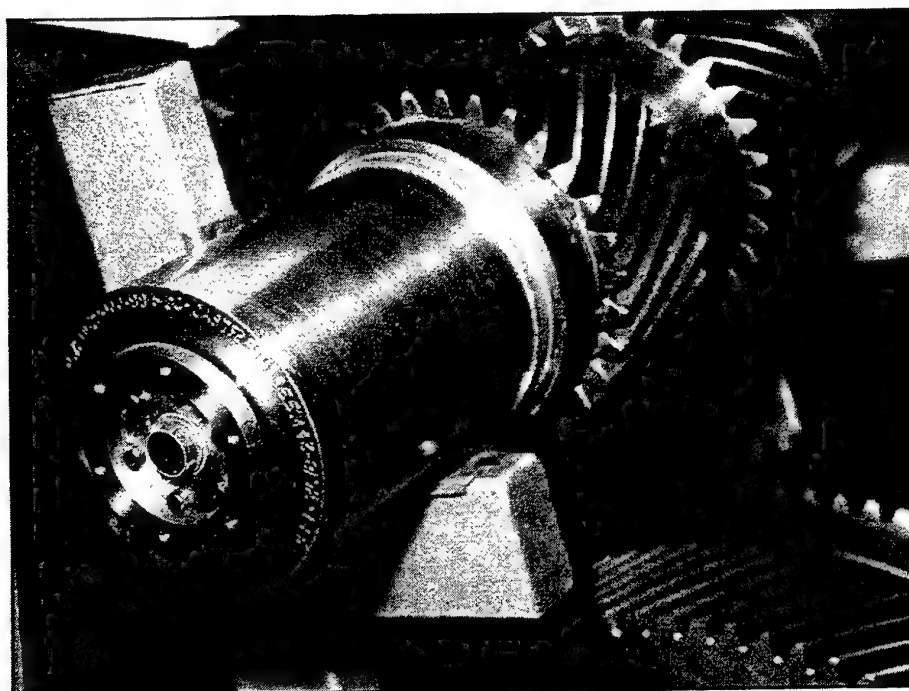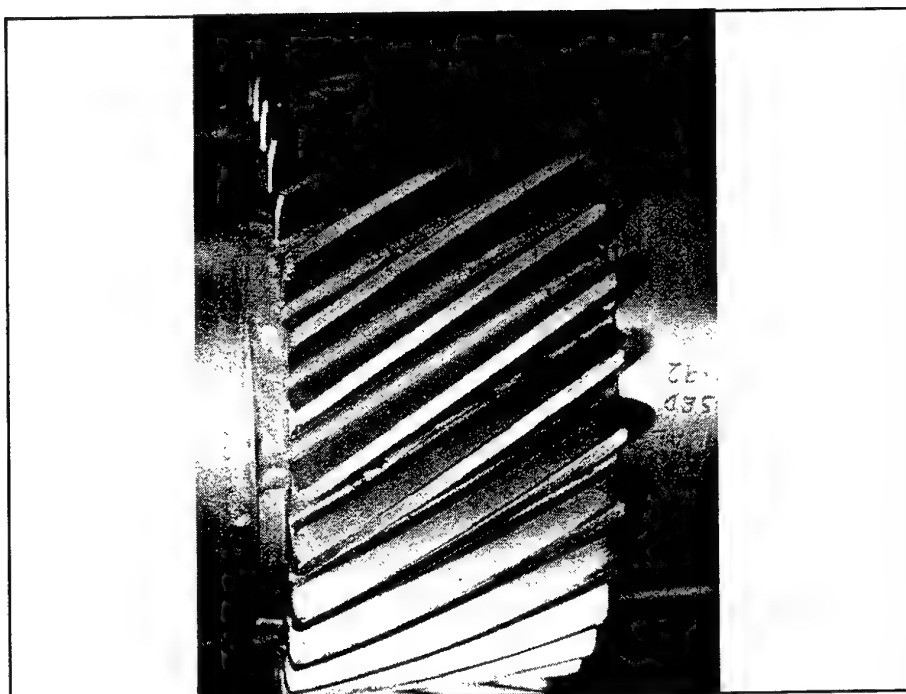
Rosinski - 13

Rosinski - 14

GEAR DYNAMICS
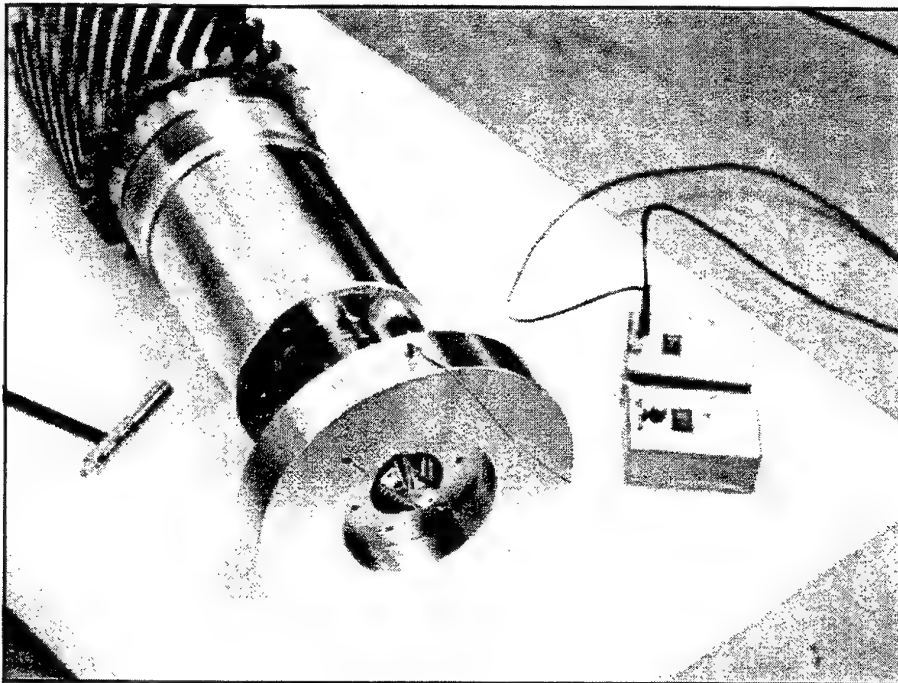
Rosinski - 15
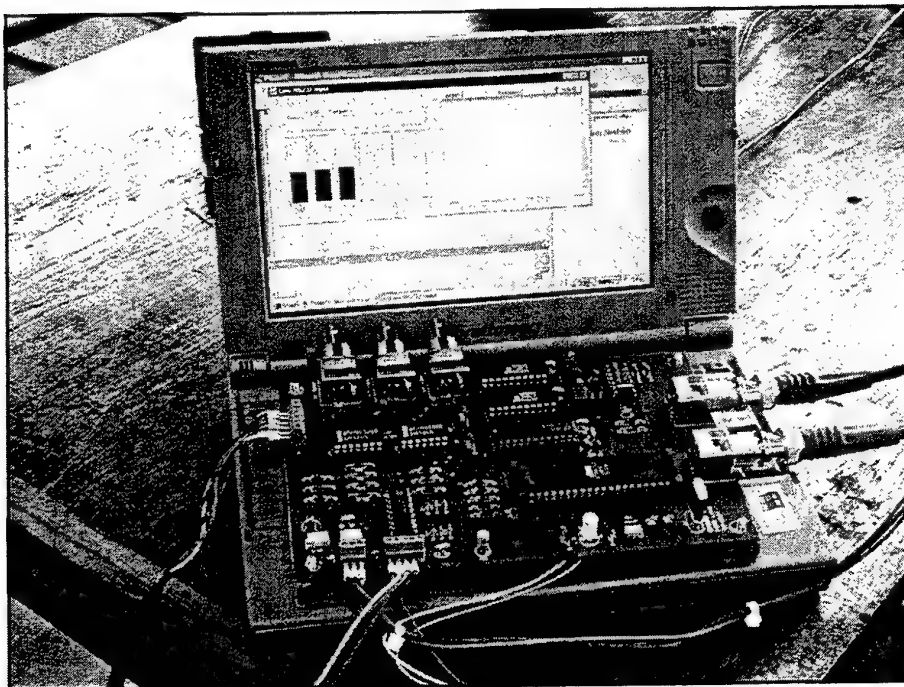
TROUBLESHOOTING TRANSMISSION SYSTEMS

Rosinski - 16
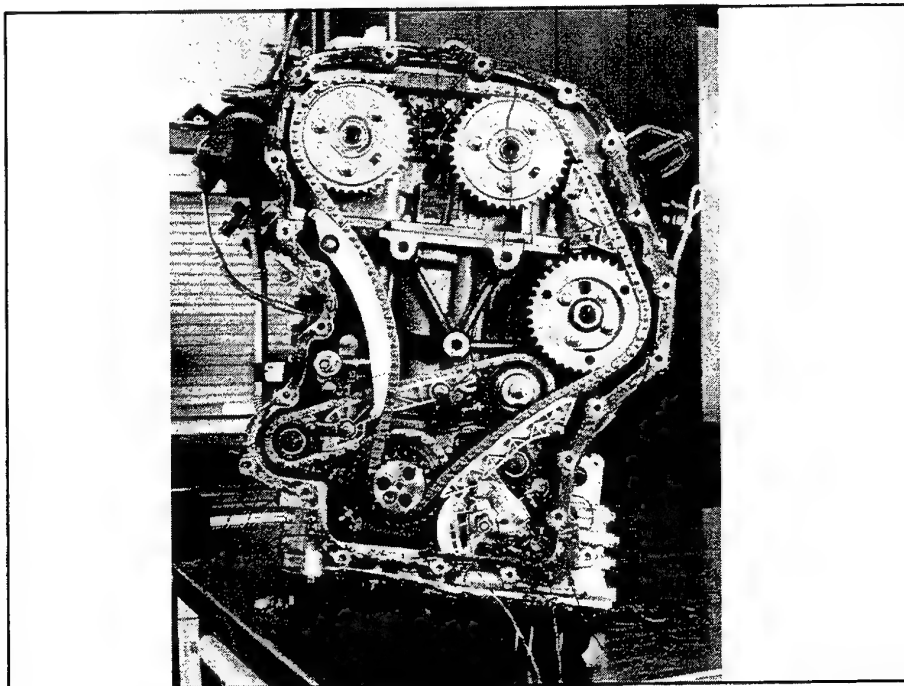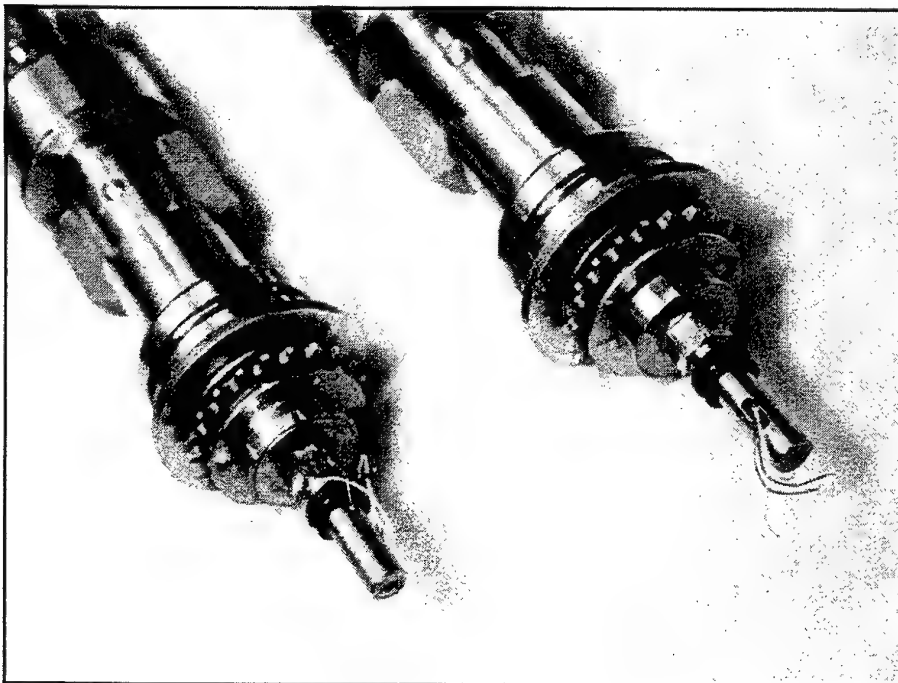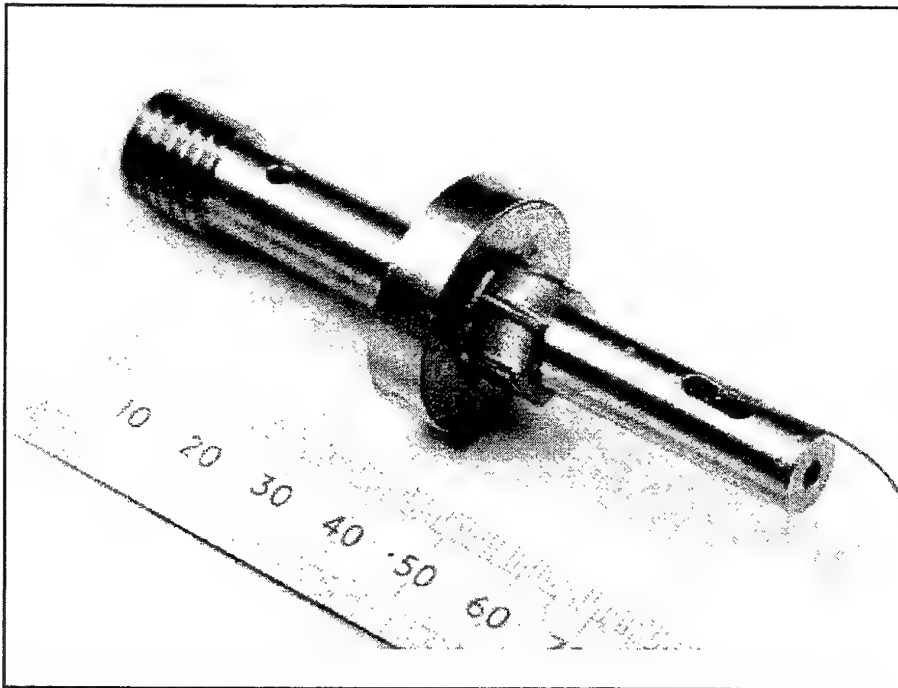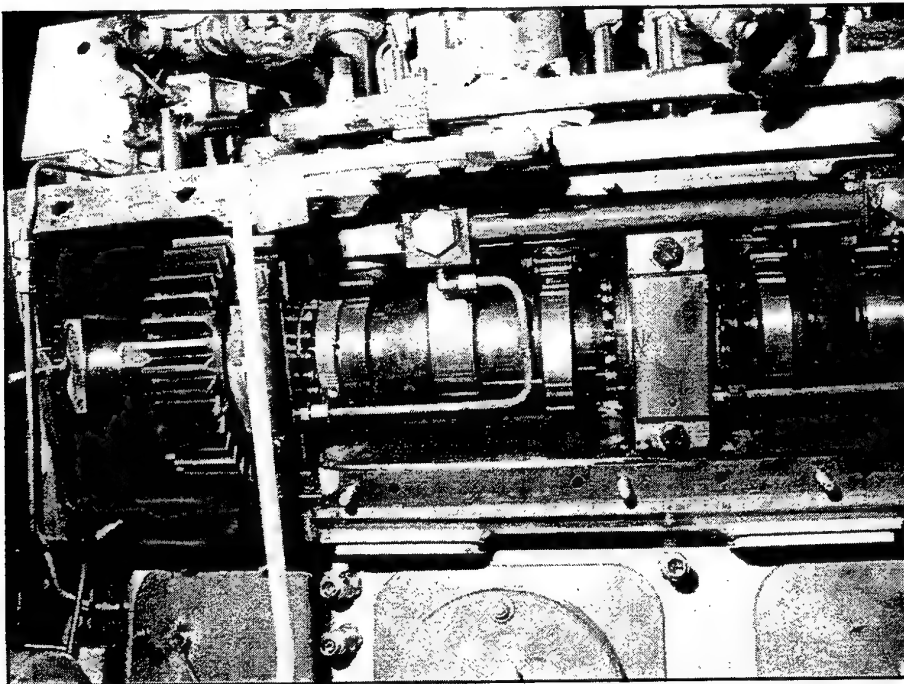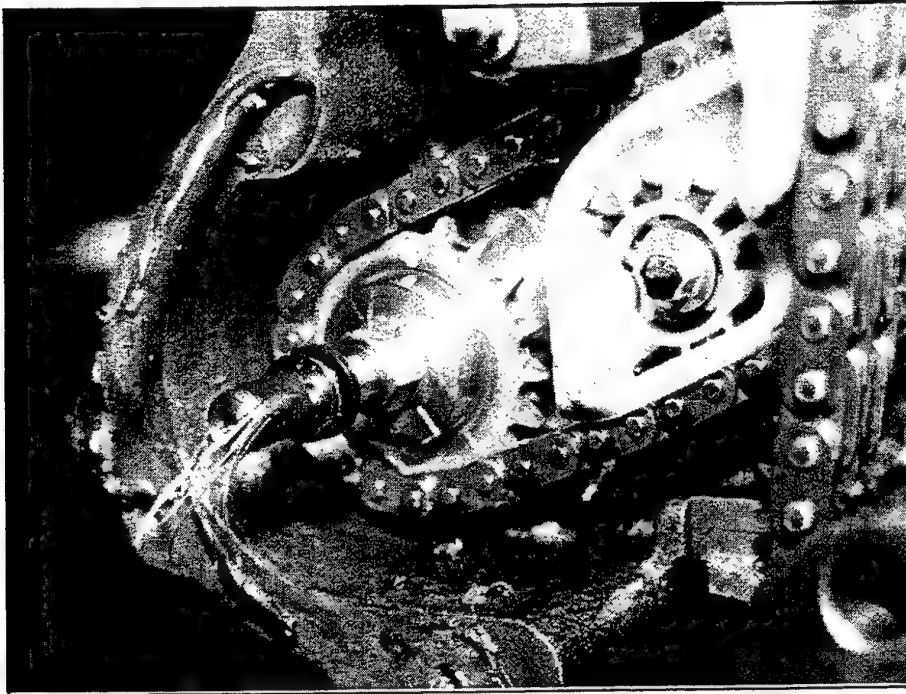
Rosinski - 17

Rosinski - 18
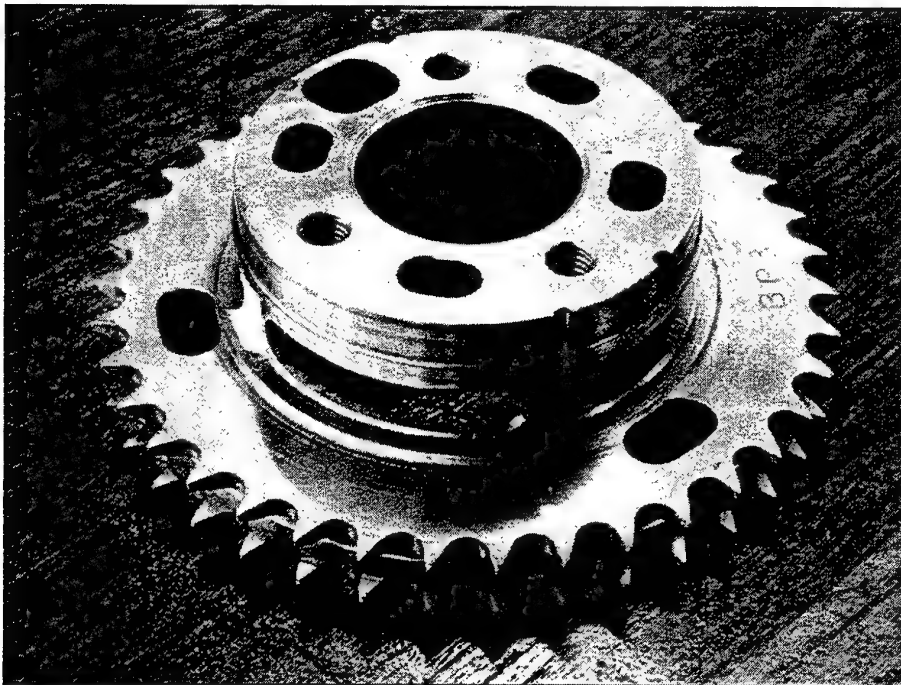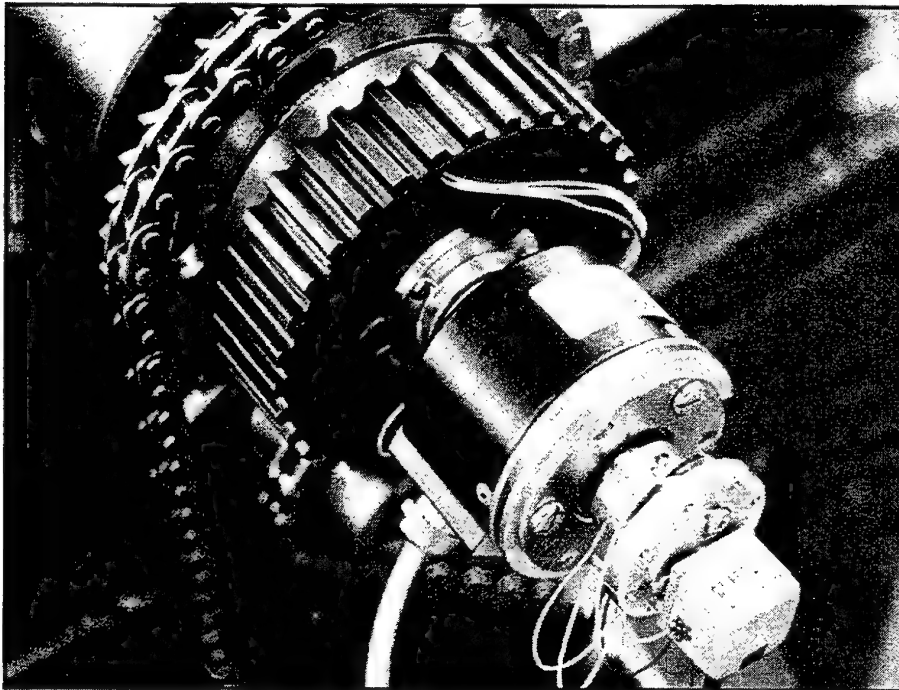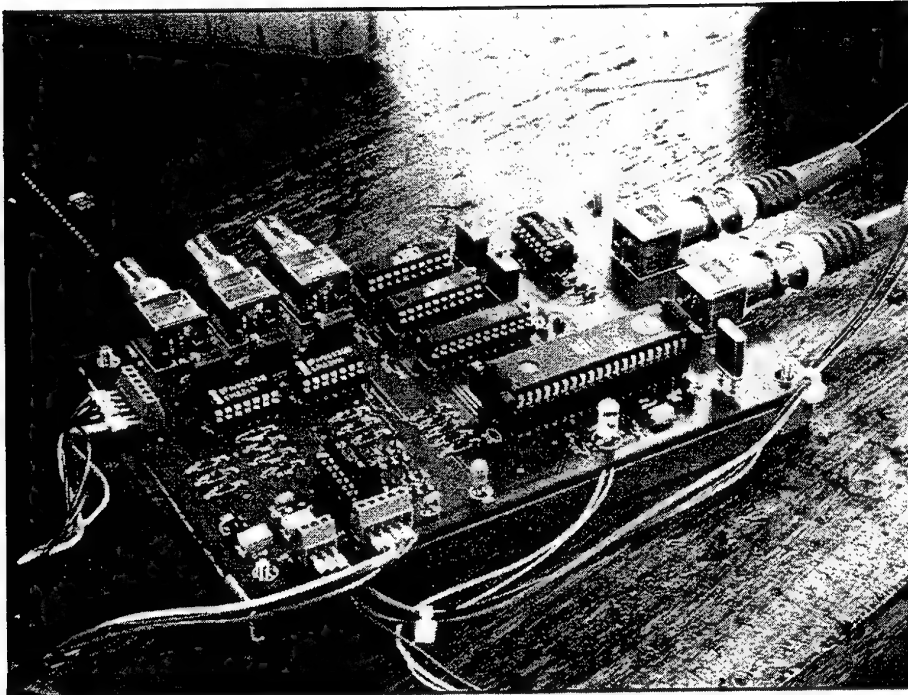
Rosinski - 19

Rosinski - 20

3-D GEAR MODELLING

Rosinski - 21

First gear pair / operating torque 240 Nm
misalignment 17 mu hard input end
Intermediate tip-relief
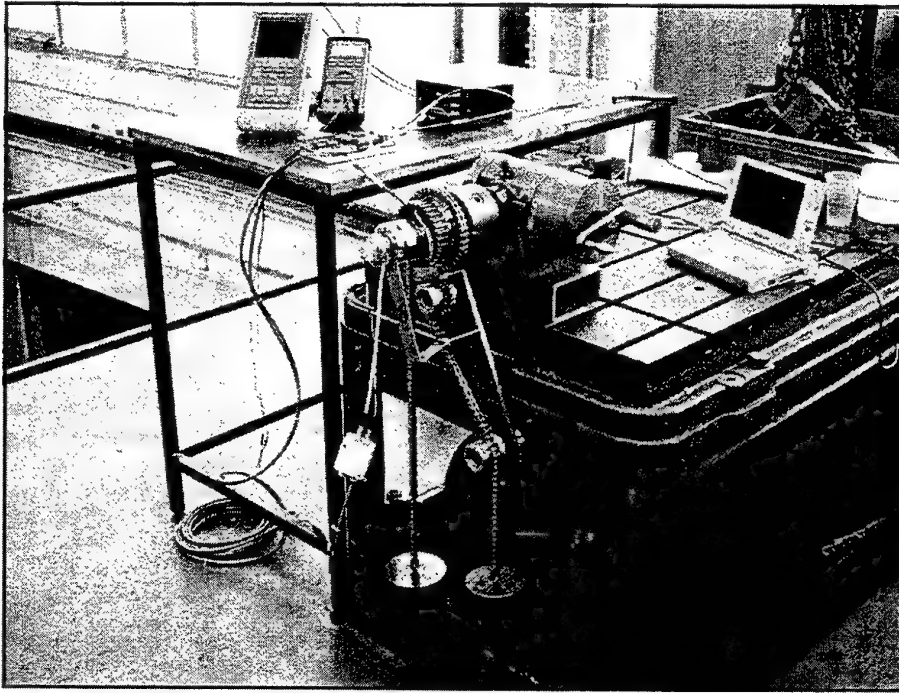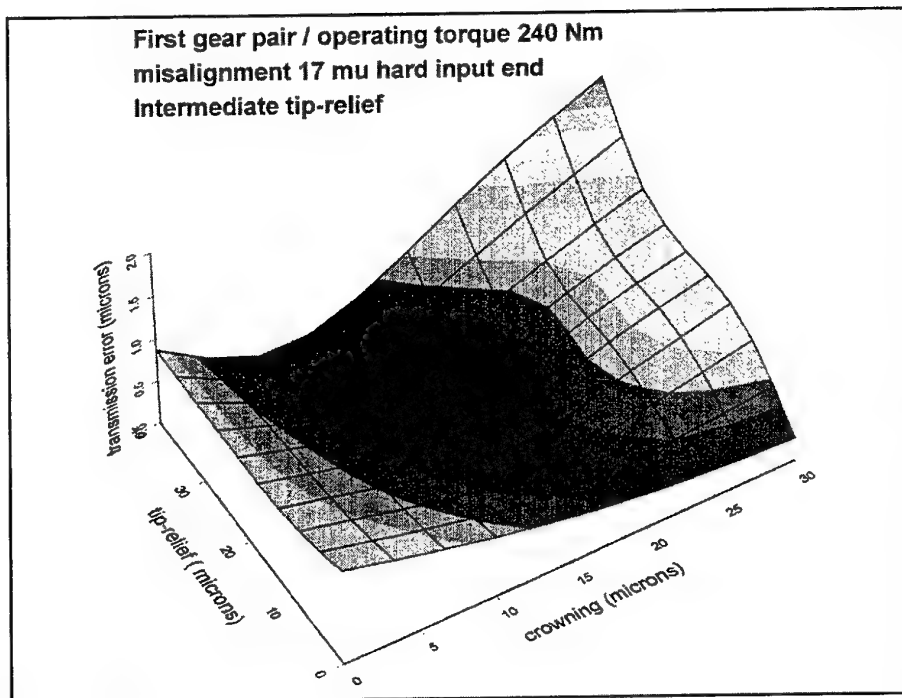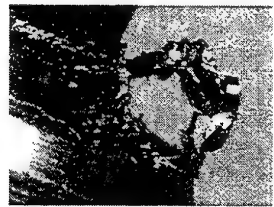
DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

RESEARCH INTO SENSITIVITY OF ELECTRIC CHIP DETECTORS (ECDs), AS INSTALLED IN ADF BLACK HAWK HELICOPTERS

SPLASH LUBRICATED ENVIRONMENT IN AN INTERMEDIATE GEARBOX

"A NON-PLANAR BRIDGE" ➡️

Presenter:

Grier McVea

Airframes and Engines Division

DSTO

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

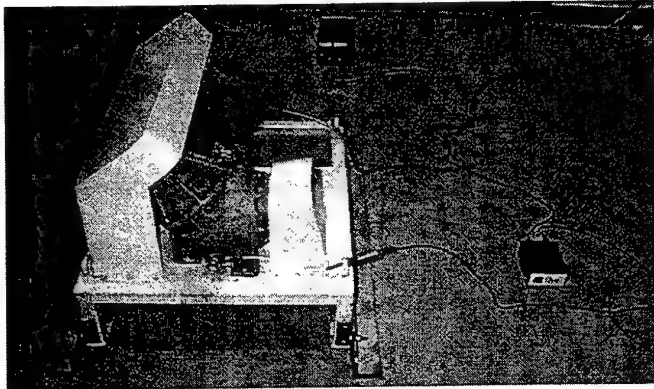## Current operational mode of Electric Chip Detectors (ECDs) for Helicopter IGB

- ECD Warning Light activates in cockpit

- Land, check and remove material from ECD

- Replace ECD, ground run 1 hour

- If there is an increased amount of metal particles

  Gearbox is removed and sent to OEM for overhaul

Airframes and Engines Division

DSTO

McVea - 1

McVea - 2

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

1 hour, 30 mg/L

2 hours, 60 mg/L

ECD magnetic chip collections in the running IGB rig, with NO warning light activation.

Indicates very low sensitivity of the radial ECD.

3 hour, 120 mg/L

Airframes and Engines Division

DSTO

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

Gearbox component failure was finally recorded when the oil system was over-dosed with huge quantities (250mg/L) of simulated wear debris (iron filings).

Bridge was made with a non-planar arrangement of debris

Airframes and Engines Division

DSTO

McVea - 4
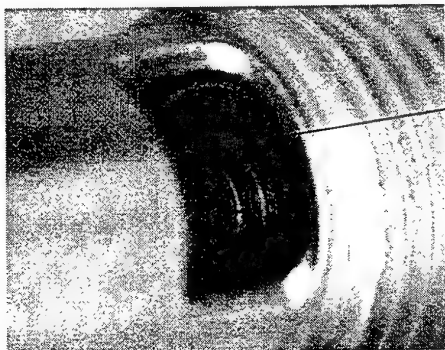
Current operational mode of Radial Electric Chip Detectors (ECDs) for IGB Health

Conclusion:

- Current **Radial ECDs** located in IGBs appear to be **very insensitive** to wear debris accumulation within the gearbox

- Stronger magnets would provide earlier warning

Airframes and Engines Division

DSTO

Planned further Black Hawk IGB Work

To study effects on ECD capture efficiencies with

- increased oil temperatures

- introduced vibration

Airframes and Engines Division

DSTO

McVea - 6

HEALTH AND USAGE MONITORING SYSTEM FOR THE ROOIVALK COMBAT SUPPORT HELICOPTER

C.J. Botes

Analysis, Management & Systems (Pty) Ltd

338 16ᵗʰ Road, Halfway House, 1685

South Africa

Abstract

The Health and Usage Monitoring System (HUMS) developed for the Denel Aviation Rooivalk CSH forms an integral part of the System Status Monitoring (SSM) capability of the aircraft. It provides an on-board capability to monitor and report *basic aircraft* health, usage on critical components, status, performance and limits exceedances to both the air and ground crews.

The HUMS comprises of the following elements:

a) Two Health Monitoring Units (HMUs) which include the Master Warning electronics;

b) Vibration Monitoring Unit (VMU);

c) Refuel/Defuel Unit (RDU);

d) Crash Recorder Unit (CRU) (optional);

e) Mission Planning and Ground Support Station;

f) Set-up and Diagnostics Station.

This is an excellent example of a fully integrated HUMS with all the associated benefits of minimising the number of Line Replaceable Units (LRUs) on-board the aircraft.

1. Introduction

The Health and Usage Monitoring System (HUMS) on-board the Denel Aviation Rooivalk CSH forms a integral part of the System Status Monitoring (SSM) capability dedicated to monitoring the basic aircraft system by means of a large number of sensors distributed throughout various parts of the aircraft.

The HUMS provides the Rooivalk CSH with an on-board capability to monitor and report *basic aircraft* health, usage on critical components, status, performance, limits exceedances and exceptions, to both the air and ground crews via the Integrated Management System (IMS).

The *basic aircraft* is defined to include the airframe, airborne avionics systems, powerplant and transmission systems.

The relationship between the SSM, IMS, HUMS and *basic aircraft* is best described as shown in figure 1.

The objectives of the SSM is to:

a) Provide the aircrew with the information necessary to ensure a high degree of confidence that the aircraft is fit for flight and airworthy at any point in time.

b) Inform the aircrew in the event of system failure, either through malfunctioning or battle damage, with information necessary to:

c) Make the correct mission related decisions;

d) Make the correct decisions related to optimised management of the remaining aircraft capabilities.

e) Provide the aircraft support system with the correct information to enable effective

Botes - 1

maintenance and support of the aircraft, both in the long and short term. This includes operational support.

f) Provide the accident investigation team, in the event of an accident, with information necessary to make the correct deductions concerning the cause of the incident.

The information required on the *basic aircraft* to meet the above objective, is acquired via the HUMS and distributed to the relevant on-board and off-board systems via the IMS. This is used to provide information for in-flight indication, but restricted to events likely to cause a mission failure. All information necessary to maintain the aircraft in a flight serviceable condition, that is health, usage and fault history, is recorded by the on-board system.

After a flight, a limited set of recorded data is available to the maintenance crew via the Multi-Function Displays (MFDs) in the cockpit. This data set is limited to information about the aircraft's fitness to fly and information to assist the maintenance crew in maintaining the aircraft. All recorded on-board data is available for downloading, via a Data Transfer Unit (DTU) to the logistic information system for further analysis.

2. Rooivalk HUMS System Design

The major sub-systems comprising the on-board equipment of the HUMS are:

a) Two Health Monitoring Units (HMUs) which include the Master Warning electronics;

b) Vibration Monitoring Unit (VMU);

c) Refuel/Defuel Unit (RDU); and

d) Crash Recorder Unit (CRU) (optional).

The off-board equipment consist of the following:

a) Mission Planning and Ground Support Station;

b) Set-up and Diagnostics Station.

The HUMS system architecture and interfaces are shown in figure 2.

The HUMS architecture reflects a combination of historical events as well as specific requirements relevant to the role of an attack helicopter.

In terms of the history, the previous architecture on the ADM Rooivalk CSH implements the current HUMS functionality in 14 separate LRUs distributed all over the aircraft. The subsequent development phase required a substantial mass reduction of the aircraft, which led to the large-scale integration of separate LRUs into the current HUMS.

Due to the fact that this is a HUMS for an attack helicopter with a glass cockpit design and the fact that the Master Warning Unit (MWU) resides inside the HMU, dual redundancy was required for the HMU in terms of the basic aircraft status reporting. This increases the probability of supplying information to the aircrew on which a decision can be based to complete the mission, even in the event of some battle damage being incurred.

Another unique characteristic of this HUMS architecture is the fact that the Refuel/Defuel Unit (RDU) was contracted as a part of the HUMS. Although somewhat of historical nature, the most significant reason for this is the fact that the HUMS performs the fuel management and leakage detection functions.

In summary the HUMS can be regarded as an Air Vehicle Management System, which performs the following major functions:

a) Basic aircraft status monitoring;

b) Basic aircraft health and usage monitoring;

c) Basic aircraft sub-system control and management;

The HUMS monitors the following aircraft systems:

Botes - 2

- Engines;
- Engine Air Intake System;
- Automatic Flight Control System;
- Air/Ground System;
- Air Data System;
- Airframe;
- Transmission and drive train elements;
- Rotor System;
- Fuel System;
- Fire Detection System;
- Lighting System;
- Hydraulic System;
- Electrical Power Generation Systems;
- Environmental Control System.

3. HUMS Equipment Breakdown

3.1 Health Monitoring Unit (HMU)

3.1.1 HMU Functionality

The two HMUs perform the Health and Usage monitoring function of the basic aircraft. The HMUs form a dual-redundant set for flight-critical parameters and is the interface between the Helicopter Mission Computers (HMCs) and external sources. The HMUs perform signal conditioning, digital encoding, processing, analysing and conveying of data to the avionics bus. In the case of the fuel system they perform the fuel management function, with the exception of the refuel/defuel function.

The HMUs are physically identical units up to pin level, while the software identify each HMU as either HMU1 or HMU2 by the individual looming connections.

The master warning capability is physically located within the HMU and is totally independent from the other functions performed by the HMUs. Each master warning unit within its respective HMU contains its own power supply and is backed up by the HMU power supply. Warnings are provided via the aircraft annunciator panel.

The HMU performs the following major functions:

a) Data acquisition, conversion and validation of basic aircraft sensor data;

b) HUMS data processing and analysis (models);

c) Mode, time and regime handing;

d) Built in test, error handling and event handling;

e) Sub-system excitation and control, e.g. Fuel management and Environmental control;

f) Data reduction, storage and management;

g) Data reporting to various sub-systems;

h) Independent master warning function that couples basic aircraft warning and alarms to the annunciator panels;

i) On-board set-up and testing.

A HMU hardware functional block diagram is shown in figure 3.

3.1.2 HMU Characteristics

The HMU hardware was fully designed, developed and manufactured by AMS. The on-board processing of the basic aircraft data was implemented by AMS as defined in the models supplied by Denel Aviation. This required close co-operation with Denel Aviation in order to ensure that the basic aircraft interfaces are implemented to meet these requirements. The HMU utilises a convection cooled ¾ ATR packaging with a power capacity of 120 Watts. The 10 slot backplane provides a IEEE 1296 MultiBus II interface between the MIL-STD-1389D (SEM-E) processor and I/O modules. The hardware characteristics can be summarised as follows:

3.1.2.1 HMU Processor Module (1x)

- Intel 80960 32-bit RISC processor (25 MHz).
- 2 Mbyte Static RAM.
- 2 Mbyte Flash Memory.

Botes - 3

105

↳ IEEE 1296 compatible MultiBus II interface.

↳ Two independently programmable serial ports (RS422 & RS232).

↳ Facilitates the onboard processing of all data acquired from the aircraft systems as defined in the C-language based HMU960 CSCI.

3.1.2.2 1553B Processor Module (1x)

↳ Intel 80960 32-bit RISC processor (25 MHz).

↳ 2 Mbyte Static RAM.

↳ 2 Mbyte Flash Memory.

↳ IEEE 1296 compatible MultiBus II interface.

↳ Two independently programmable serial ports (RS422 & RS232).

↳ Dual redundant MIL-STD-1553B bus interface as Bus Controller, Remote Terminal or Bus Monitor.

↳ Facilitates the onboard processing required for data reporting on the 1553B databus as defined in the C-language based I/O960 CSCI.

3.1.2.3 General I/O Module (1x)

↳ Provide 96 multi-level discrete inputs between 0 and 28V, programmable in steps of 150mV of which 48 is opto-isolated.

↳ Provide 16 discrete outputs capable to sink/source up to 25V at 100mA continuous of which 8 is opto-isolated.

↳ This module functions as a slave MultiBus II interface.

3.1.2.4 Dedicated I/O Module (1x)

↳ Accepts up to 192 multi-level discrete signals from the aircraft and converts the 28V signals to TTL compatible signal.

↳ Inputs are programmable between 0 and 28V in steps of 150mV capable of either sink or source current.

↳ Provide 8 discrete outputs with full short circuit protection.

↳ This module functions as a slave MultiBus II interface.

3.1.2.5 Comms and Tacho Module (1x)

↳ Intel 80386 32-bit processor (16 MHz).

↳ 4 Mbyte Flash Memory.

↳ Serial communication includes 3x RS232 ports, 3x RS485 ports, 1x RS485/RS422 SDLC port, 2x ARINC 429 inputs, 1x ARINC 429 output and 1x Harvard BI-Phase port.

↳ Accepts up to 32 multi-level discrete signals from the aircraft and converts the 28V signals to TTL compatible signal.

↳ IEEE 1296 compatible MultiBus II interface.

↳ 6x Tacho inputs (0-20kHz and 0-5kHz).

↳ Facilitates the onboard processing required for data reporting on the 1553B databus as defined in the C-language based I/O960 CSCI.

3.1.2.6 General Analogue Module (3x)

↳ Provides all sensor excitations and stimulus.

↳ Provides 12 bit resolution ADC and DAC with associated filtering to monitor all analogue signals.

↳ Analogue signals catered for are 10x differential input DC voltages, 3x differential input AC voltages, 1x differential input AC current, 2x differential input DC currents, 6x resistive temperature sensor inputs, 2x potentiometer inputs and 12x excitations.

↳ This module functions as a slave MultiBus II interface.

3.1.2.7 Master Warning Module (1x)

↳ Operates independently from other HMU modules and is powered from a separate power source.

Botes - 4

🖑 BIT circuitry reported back to the HMU.

🖑 Provides the interface between aircraft sensors and the annunciator panels to indicate the following:

➤ Engine fire

➤ Pilot initiated reset

➤ Engine low pressure

➤ Power loss/faults in engines

➤ Low fuel quantities

➤ Low/High NR

➤ Rotor-brake status

➤ Low gearbox oil pressures

➤ Shutoff valve status

➤ Main gearbox fire

➤ Delta between NG1/NG2 out of limits

➤ Low cross-feed pressures between fuel tanks

➤ AFCS not functional

3.2 Vibration Monitoring Unit (VMU)

3.2.1 VMU Functionality

The Vibration Monitoring Unit performs vibration related health analysis on the engines and drive-train elements of the aircraft and acquires vibration and track information in order to perform rotor track and balance.

The mission of the VMU is to improve aircraft safety by early detection of component degradation before secondary damage or catastrophic failure and to supply intelligent diagnostic information, which can be used as a maintenance tool to give an indication of defective components without removing the components for inspection. This is accomplished by analysing the vibration response of the different components using dedicated vibration sensors and the accompanying acquisition and analysis hardware and software.

The system initiates the execution of the appropriate algorithms in accordance with specific

ground and flight regimes in order to minimise interaction with the aircrew.

The emphasis of the system design is to provide an early alarm of any vibration related abnormalities which may endanger the aircrew or aircraft life.

The VMU makes provision to monitor the following systems:

a) Rotor System

🖑 Main rotor system.

🖑 Tail rotor system

b) Engines 1 & 2

c) Transmission System

🖑 Coupling gearboxes 1 & 2

🖑 Main gearbox

🖑 Intermediate gearbox

🖑 Tail rotor gearbox

🖑 Oil cooler fans

d) Drive Shafts

🖑 Tail rotor drive shafts, couplings and hanger bearings

🖑 Drive shafts between MGB and CGB

🖑 Drive shafts between engine and the CGB.

The VMU performs the following major functions:

a) Data acquisition, conditioning, validation and signal processing;

b) Vibration analysis on the aircraft gearboxes, critical bearings, engines, critical shafts, main and tail rotors;

c) Acquisition and analysis scheduling according to the current flight regime or commands via the HMU;

d) Data storage and management;

e) Exceedance detection and reporting;

f) Built in test;

g) Communication with the HMU and SDS over serial channels.

Botes - 5

A VMU hardware functional block diagram is shown in figure 4.

3.2.2 VMU Characteristics

The VMU hardware was fully designed and developed by AMS. The software development was performed by AMS in co-operation with UK based MJA Dynamics (MJAD), who supplied all the vibration diagnostic algorithms. These algorithms were defined by MJAD for implementation by AMS, while the acquisition software was an AMS development. This required close co-operation AMS, MJAD and Denel Aviation to ensure that all the detail geometrical data of the drive train were reflected in the detail algorithm implementation. The VMU utilises a convection-cooled ½ ATR packaging with a power capacity of 45 Watts. The 5 slot backplane provides the MultiBus II interface between the MIL-STD-1389D (SEM-E) processor and I/O modules. The hardware characteristics can be summarised as follows:

3.2.2.1 VMU Processor Module (1x)

- ✎ Intel 80960 32-bit RISC processor (25 MHz).

- ✎ 2 Mbyte Static RAM.

- ✎ 2 Mbyte Flash Memory.

- ✎ IEEE 1296 compatible MultiBus II interface.

- ✎ Two independently programmable serial ports (RS422 & RS232).

- ✎ Facilitates the acquisition process control and onboard diagnostic calculation of all data acquired from the drive train elements as defined in the C-language based Control and Diagnostic CSCI.

- ✎ This CSCI calculates all the dimensionless 12x Gear indices, 7x Bearing indices, Engine indices, Shaft indices, Main RTB indices and Tail balance indices.

3.2.2.2 Vibration Acquisition Module (1x)

- ✎ DSP based (TMS320C31) floating point processor.

- ✎ Two simultaneous acquisition channels, each with 15 multiplexed inputs, 30 accelerometer interfaces in total.

- ✎ Provide for a total of 8 tacho signal interfaces, 6 magnetic type inputs and 2 TTL compatible inputs.

- ✎ Provide for a tracker interface via RS485.

- ✎ Provide accelerometer excitation constant current source of 4.6mA at 28Vdc for each channel.

- ✎ Software selectable Gain Amplifiers, High Pass Filters and Internal Clock, 8th order elliptical Anti-alias filter, 12bit Analogue to Digital Converter and 24bit resolution Period Counter with 16.5MHz clock frequency.

- ✎ 2 Mbyte Dynamic Memory used for storage of acquired data.

- ✎ Facilitates the acquisition process and pre-processing to determine the signal and power averages required by the diagnostic algorithms as defined in the C and Assembler language based Acquisition CSCI.

3.3 Refuel/Defuel Unit (RDU)

3.3.1 RDU Functionality

The RDU automates the process of pressure refuelling and de-fuelling and provides fuel quantity measurement and tank leakage information on a continuous basis to both HMUs.

The front face of the unit forms the man-machine interface when performing the refuel/defuel function. The RDU performs the following major functions:

a) Automatic control of the pressure refuel/defuel process on-board the aircraft;

Botes - 6

b) Prime fuel measurement system on-board the aircraft; and

c) Internal tank leakage detection and associated tank inhibition.

3.3.2 RDU Characteristics

AMS and Denel Aviation jointly specified the RDU and the development was sub-contracted to INTERTECHNIQUE in France. Due to the limited applicability of the RDU to HUMS in general, no further detail is supplied in this paper.

3.4 Crash Recorder Unit (CRU)

3.4.1 CRU Functionality

The CRU records all data for accident/incident investigations and is connected to both HMU1 and HMU2 via a Harvard bi-phase link. The primary source of data is from HMU1 and in the event of HMU1 failure HMU2 will take over the function. The CRU implementation was designed to be EUROCAE ED55/56A compliant while the actual fit is provided as a customer option.

3.4.2 CRU Characteristics

The CRU for the Rooivalk CSH is regarded as on off-the-shelf item with no development work required. Currently the BASE SCR500 CVFDR is proposed as a customer option. Up to 25 hours of flight data and 2 hours of voice data (4x channels) can be stored.

3.5 Off-board HUMS Sub-systems

3.5.1 Set-up and Diagnostic Station (SDS)

This function is implemented on a portable PC with a serial interface (RS232) to the unit under test. It is used to up-load configuration data to the relevant HUMS on-board equipment. It is also used to perform limited testing of the on-board equipment to enable confirmation of failed equipment. Software revision upgrades is also facilitated via the SDS without opening the onboard equipment. From an OEM/Operator

point of view, the SDS is used as an aircraft installation tool to verify sub-system functionality as installed on the aircraft.

3.5.2 Mission Planning and Ground Support Station (MGSS)

The Mission Planning and Ground Support System is a computerised facility that will be deployed with the Rooivalk CSH to allow the flight crew to perform on-line and off-line mission planning and debriefing, and the maintenance support crew to perform, configure and document aircraft logistic analysis and support actions. The MGSS System primarily consists of the following major components:

- ✍ MGSS computer hardware platform.
- ✍ Ground Data Transfer Unit (GDTU).
- ✍ Mission Planning and Debriefing software application Module (MPDM).
- ✍ Data Transfer/Translator software application Module (DTTM), which will be a library part of the MPDM (possible a DL).
- ✍ Maintenance Data software applications Module (MDM).

For the purposes of this paper, only the MDM will be discussed further as this is relevant to the HUMS implementation.

3.5.2.1 Maintenance Data Module (MDM)

The MDM shall be a tool in aid of the maintenance support crew that will facilitate th eplanning, transfer, debrief, analysis and processing of maintenance (logistic) information of the aircraft in order to provide maintenance management support for the complete Rooivalk CSH.

The MDM shall have the following capabilities:

- ✍ Provide the ground support crew with the capability to ensure that all aircraft at squadron or aircraft "deployed" within a

Botes - 7

109

flight/element are maintained and supported at all times.

↳ Provide the support crew with the capability to accurately diagnose aircraft system level faults, usage, health and performance, and to prognose possible failures from the data acquired by means of the aircraft on-board system. This entails:

↳ Processing and Analysis of the captured on-board data suing the HUMS Expert Analysis and Fault Diagnostics (FD) modules.

↳ Diagnostic decision support to diagnose and isolate system level faults using the FD module and Reference Information (Refinfo) module.

The MDM consists of the following main modules:

↳ SLIS Module

↳ RefInfo Module

↳ Fault Diagnostics (FD) Module

↳ HUMS Export Analysis Module

↳ System Utilities Module

The SLIS Module forms the primary Integrated Logistics Support Information System in the SAAF and supports force logistic application operations.

The RefInfo Module is responsible for the creation, modification, management and publishing of technical documents for both paper and interactive delivery.

The Fault Diagnostics Module is responsible for providing a decision support system that utilises logistic (SLIS) and system data to assist maintenance personnel to achieve efficient fault diagnosis.

The HUMS Expert Analysis Module is responsible for providing a processing and analysis function to generate performance information from the Rooivalk on-board HUMS systems. For example:

↳ Fault Isolation and Model Inversion Analysis

↳ Go/No-Go Analysis

↳ Health Analysis

↳ Failure/Condition Analysis

↳ Event Analysis

↳ Usage Analysis

↳ Trend Analysis

The System Utilities Module is responsible for performing certain system and database, administration functions such as System Access Control, File Management, Import/Export of data, Audit Trails and Ad Hoc User Defined Reporting and Queries, etc.

The MGSS is currently still under development with Denel Aviation as the prime contractor to ensure integration of the Mission Planning and Maintenance Support functions.

4. Conclusion.

The HUMS as developed for the Rooivalk CSH is an excellent example of a fully integrated HUMS. This stems from the fact that the HUMS was designed in as part of the basic aircraft as well as the avionics, rather than an add-on system. The benefits are that duplication of functionality is minimised with the obvious associated reduction in the number of LRUs onboard the aircraft. This in turn has a mass reduction advantage and over and above the expected HUMS benefits, provides a life-cycle cost reduction benefit. This architecture also provides the flexibility to adapt the HUMS information available to the aircrew to the requirements of each specific customer.

By maximising the amount of parameters recorded by the HUMS, the future growth path is provided to include future enhancements by software upgrades, thus avoiding costly hardware upgrades.

Botes - 8

5. Acknowledgement

AMS would like to acknowledge the support of Denel Aviation with regards to the HUMS development. Further acknowledgement also to INTERTECHNIQUE on the RDU development and MJA Dynamics as the VMU algorithm supplier, who distinguished themselves as excellent partners in the development programme.

6. List of References

1. Air Vehicle System Development Specification, Document Number 08A0000TB0001, Issue E.

2. Prime Item Development Specification for the XH-2 Aircraft Health Monitor System, Document Number 08C4800TB0001, Issue 1.

3. Prime Item Development Specification for the Mission Planning and Ground Support Station, Document Number 08C1500TB0003, Issue A.

Botes - 9

List of Abbreviations

|		
AMS	:	Analysis Management & Systems (Pty) Ltd
AP	:	Annunciator Panel
ATR	:	Air Transport Racking
AIU	:	Aircraft Identification Unit
ADM	:	Advanced Development Model
CRU	:	Crash Recorder Unit
CGB	:	Central Gearbox
DECU	:	Digital Engine Control Unit
DTD	:	Data Transfer Device
DTU	:	Data Transfer Unit
ECS	:	Environmental Control System
EDU	:	Engine Data Unit
IMS	:	Integrated Management System
I/O	:	Input / Output
HMC	:	Helicopter Mission Computers
HUMS	:	Health and Usage Monitoring System
LRU	:	Line Replaceable Unit
MFD	:	Multi-Function Displays
MMI	:	Man Machine Interface
MWU	:	Master Wing Unit
MGB	:	Main Gearbox
PDS	:	Portable Data Store
RDU	:	Refuel/Defuel Unit
SDS	:	Set-up and Diagnostic Station
SSM	:	System Status Monitoring
VMU	:	Vibration Monitoring Unit

Botes - 10

List of Figures
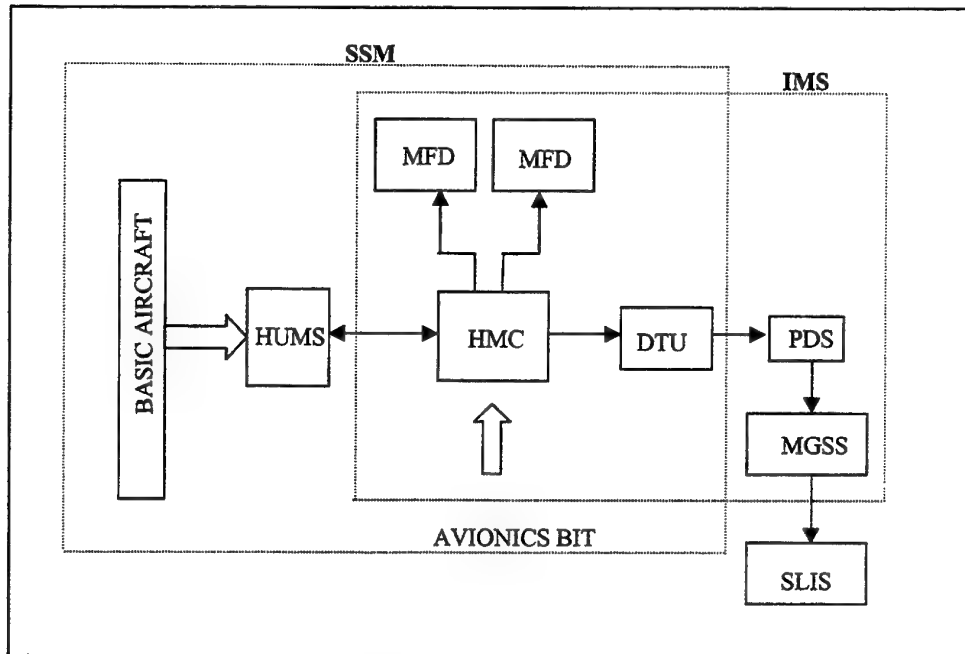
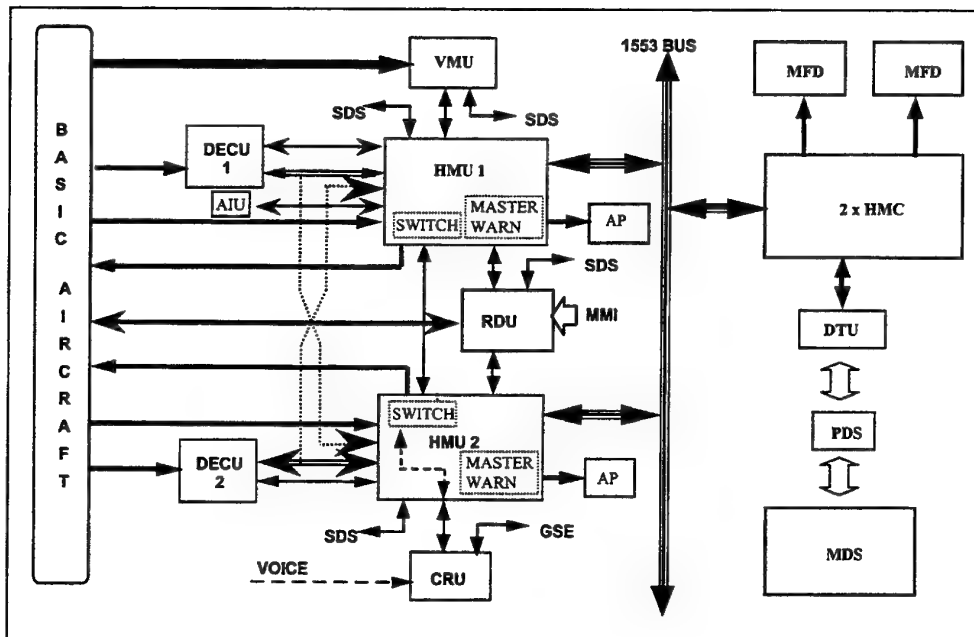**Figure 1 : SSM, IMS and HUMS Context diagram**

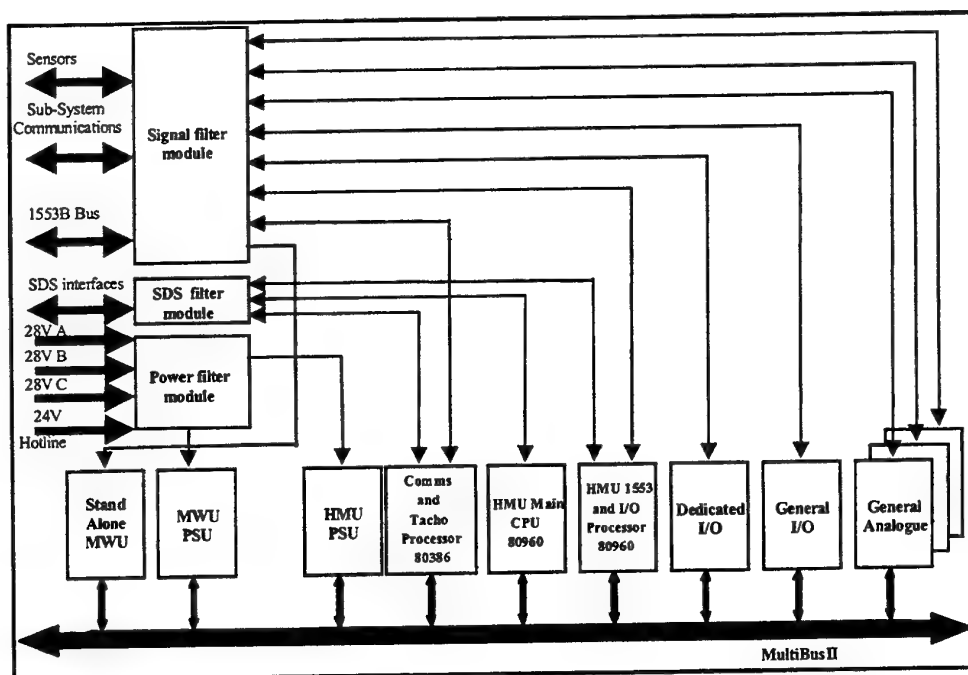**Figure 2 : Rooivalk HUMS Architecture**

Botes - 11

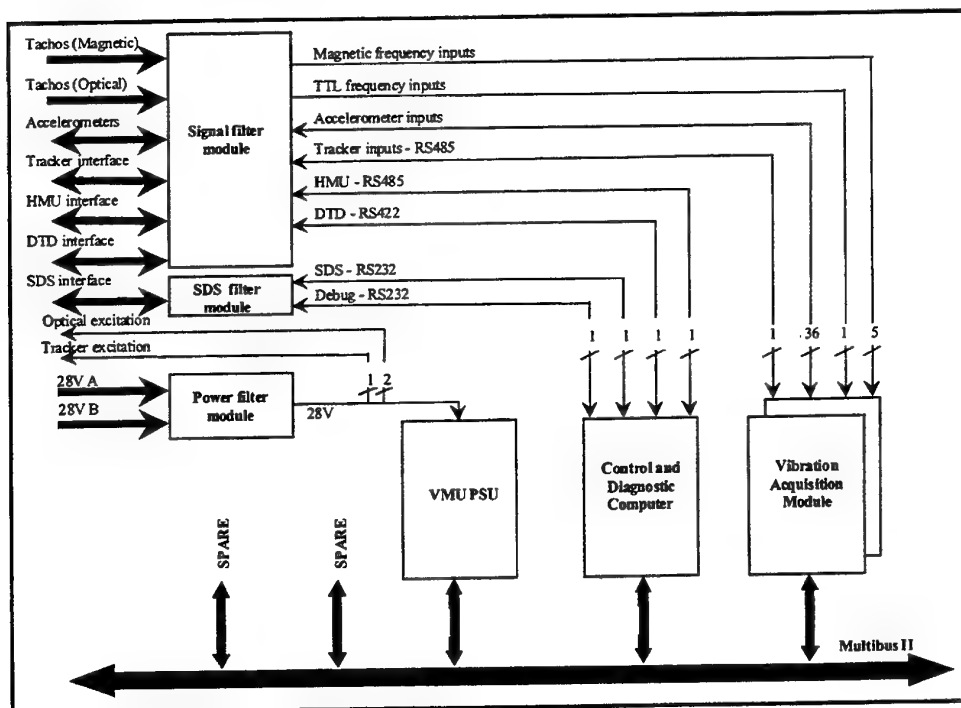**Figure 3 : HMU Hardware Functional Block Diagram**

Figure 4 : VMU Hardware Functional Block Diagram

Botes - 12

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

Presenter

Ben Parmington

Airframes and Engines Division

DSTO

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

OBJECTIVE OF THE PROGRAM

- Enhance AMRL's understanding of the operation and performance of existing and new generation oil debris monitors,

IN ORDER TO

- better position AMRL to provide advice to the Australian Defence Force on the performance of monitors used on existing aircraft and of new generation monitors that are becoming available.
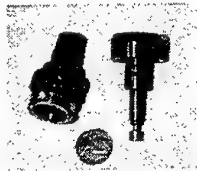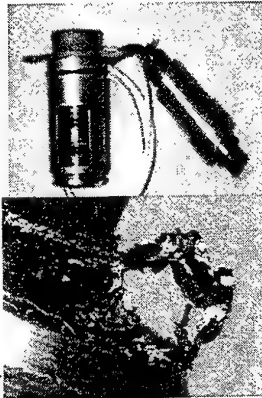
Airframes and Engines Division

DSTO

Parmington - 1

Parmington - 2
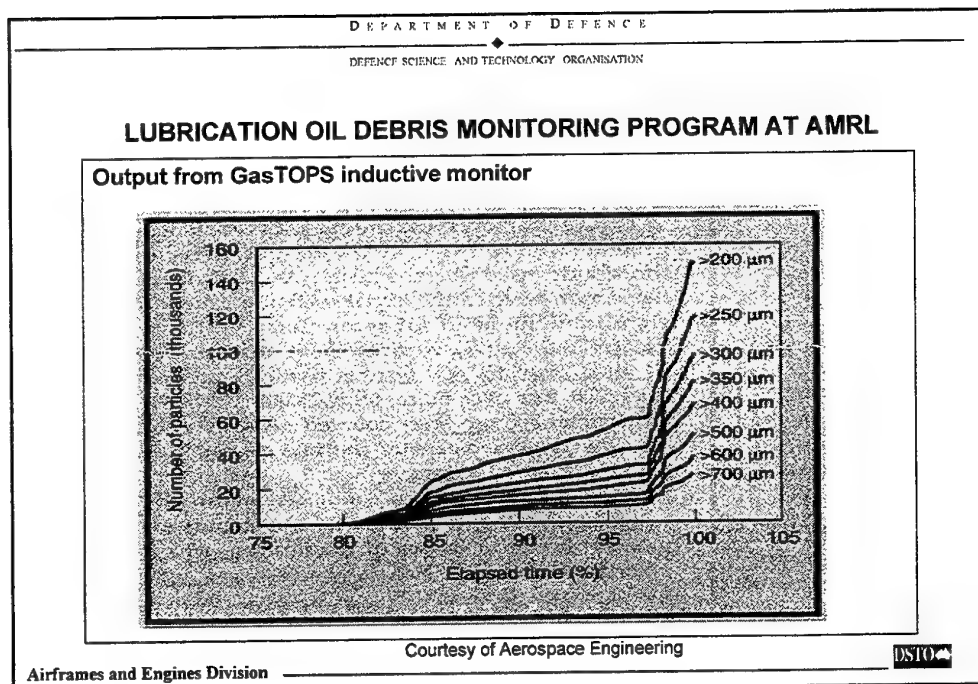
DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

Manufacturers/Developers of Advanced Inductive type In-line oil Debris monitors

GasTops Ltd of Canada: Full flow monitor capable of detecting Magnetic and non Magnetic metal particles

Tedeco US: Full flow monitor detects only magnetic particles

Thompson Power UK :   Full flow monitor detects only magnetic particles

Smiths Industries UK: Detects both magnetic and non magnetic metallic particles

Wells Krautkamer/ Manor Technology: Detects both magnetic and non magnetic metallic particles.

Airframes and Engines Division

DSTO

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

WHAT WE WANT TO KNOW

- **REGISTRATION EFFICIENCY = number particles registered versus number of particles passed**

- **STATISTICAL DISTRIBUTION OF THE REGISTRATION EFFICIENCY**
  for range of particle sizes
  at different oil temperatures
  at different oil flow rates

- **RESPONSE OF THE SENSOR TO DISTRIBUTION OF WEAR PARTICLES IN THE FLOW**
  particles widely dispersed
  cloud of particles densely packed

- **PERFORMANCE OF SENSOR AS AN EARLY WARNING MONITORING DEVICE**

- **ELECTRONIC INTEGRITY AT ELEVATED TEMPERATURES**

Airframes and Engines Division

DSTO

Parmington - 3

117

DEPARTMENT OF DEFENCE
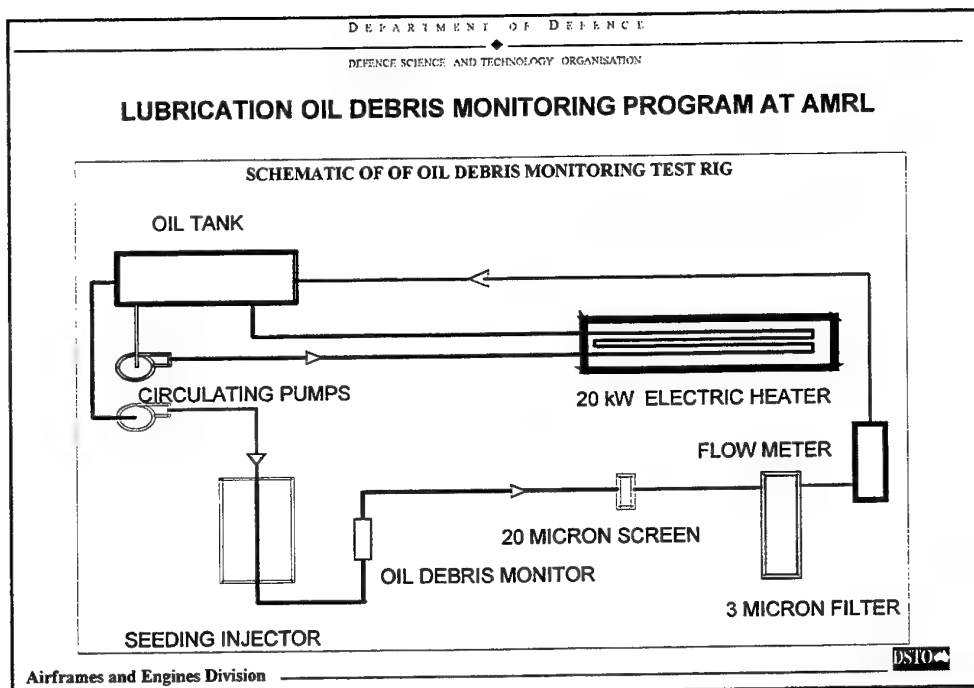
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
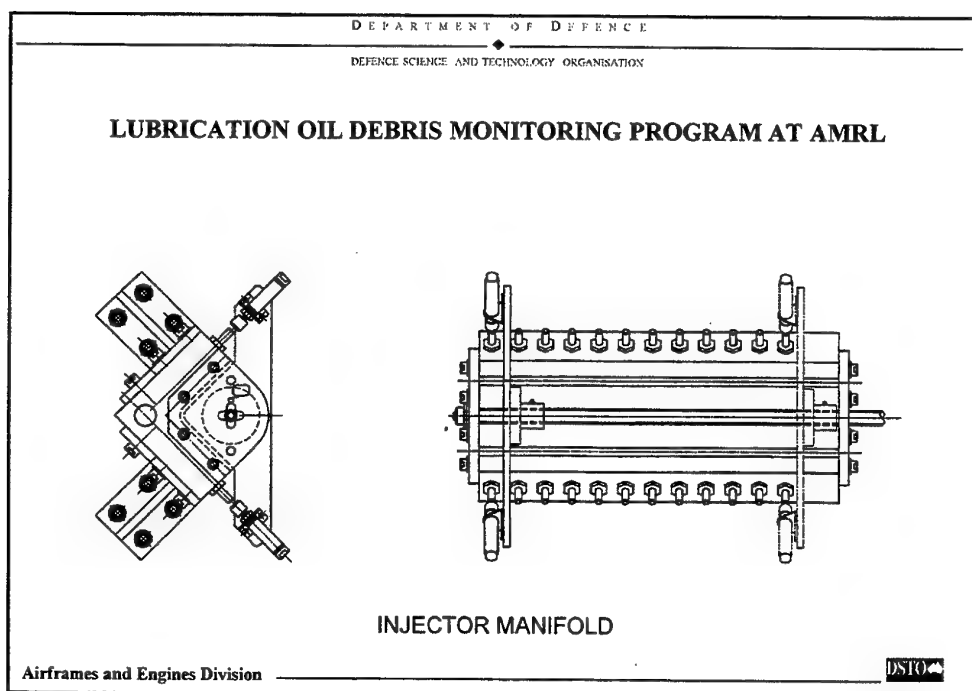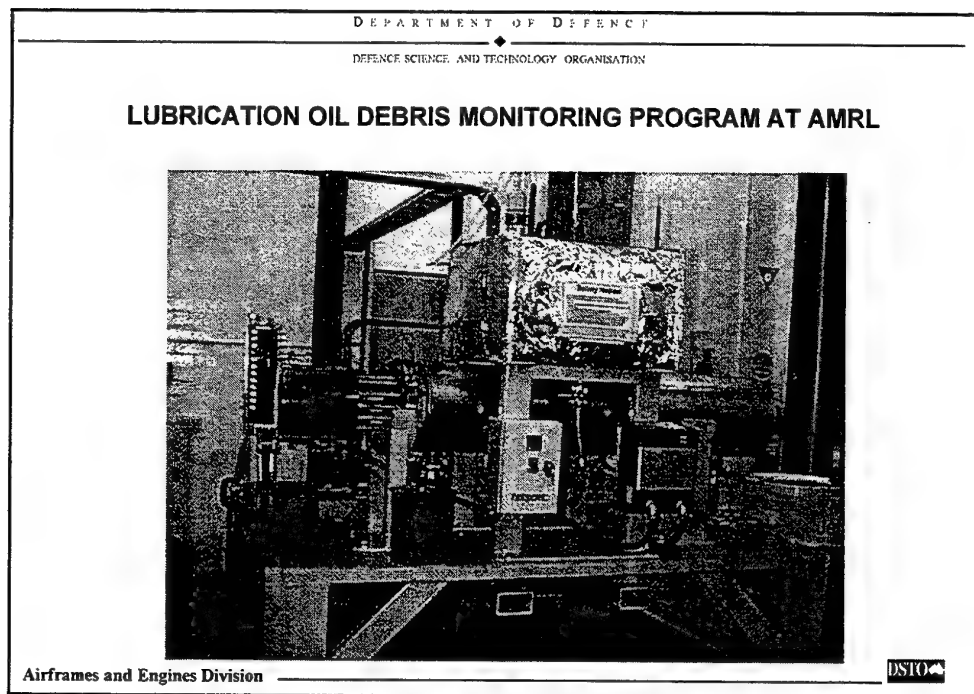
LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

WHAT IS REQUIRED OF THE RIG

- HEATING CAPABILITY OF OIL TO 200 DEGREES CENTIGRADE
- VARIABLE OIL TEMPERATURE CONTROL
- VARIABLE OIL FLOW RATE UP TO 100 L PER MINUTE
- AUTOMATED SEQUENTIAL INJECTION OF WEAR DEBRIS
- REMOTE OPERATION OF THE RIG
- WEAR DEBRIS RECOVERY FOR EVALUATION OF REGISTRATION EFFICIENCY
- PROVISION OF AERATION OF THE OIL

Airframes and Engines Division

DSTO

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

SCHEMATIC OF OF OIL DEBRIS MONITORING TEST RIG

OIL TANK

CIRCULATING PUMPS

20 kW ELECTRIC HEATER

FLOW METER

20 MICRON SCREEN

OIL DEBRIS MONITOR

3 MICRON FILTER

SEEDING INJECTOR

Airframes and Engines Division

DSTO

Parmington - 4

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

INJECTOR MANIFOLD

Parmington - 5

DEPARTMENT OF DEFENCE
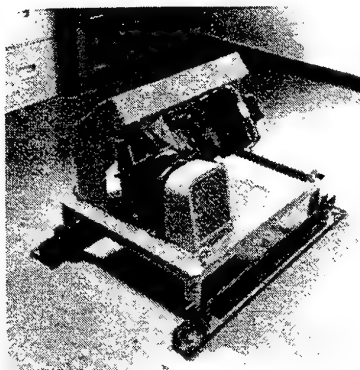
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

Wet sump gearbox

- Rig capable of duplicating oil churning rates

Cannot duplicate the effect of:

- Power input
- Gearbox running temperatures
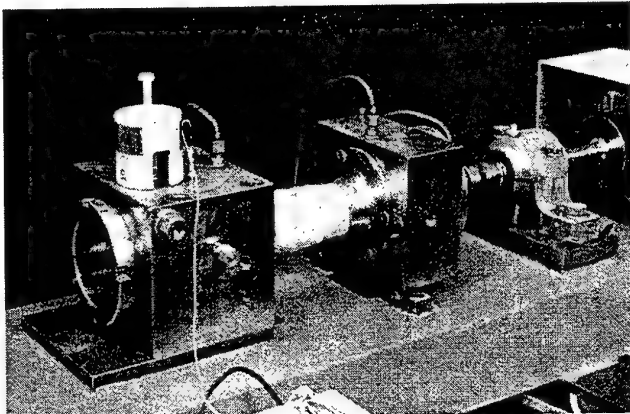- Gearbox vibration

S-70A-9 BLACK HAWK INTERMEDIATE GEARBOX RIG

Airframes and Engines Division

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

Rig for Generating Bearing Debris Material

Airframes and Engines Division

Parmington - 6

DEPARTMENT OF DEFENCE

◆

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

STATUS

- **Tests on the Black Hawk (S-70A-9) Main Rotor Gearbox sensor and GasTOPS MetalSCAN ready to start within the next fortnight.**

Airframes and Engines Division — DSTO

DEPARTMENT OF DEFENCE

◆

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

LUBRICATION OIL DEBRIS MONITORING PROGRAM AT AMRL

ANY QUESTIONS ?

Airframes and Engines Division — DSTO

Parmington - 7

Aerostructures, Inc.

Helicopter Usage Monitoring Using the MaxLife System

DSTO Helicopter HUMS Workshop -- February 1999

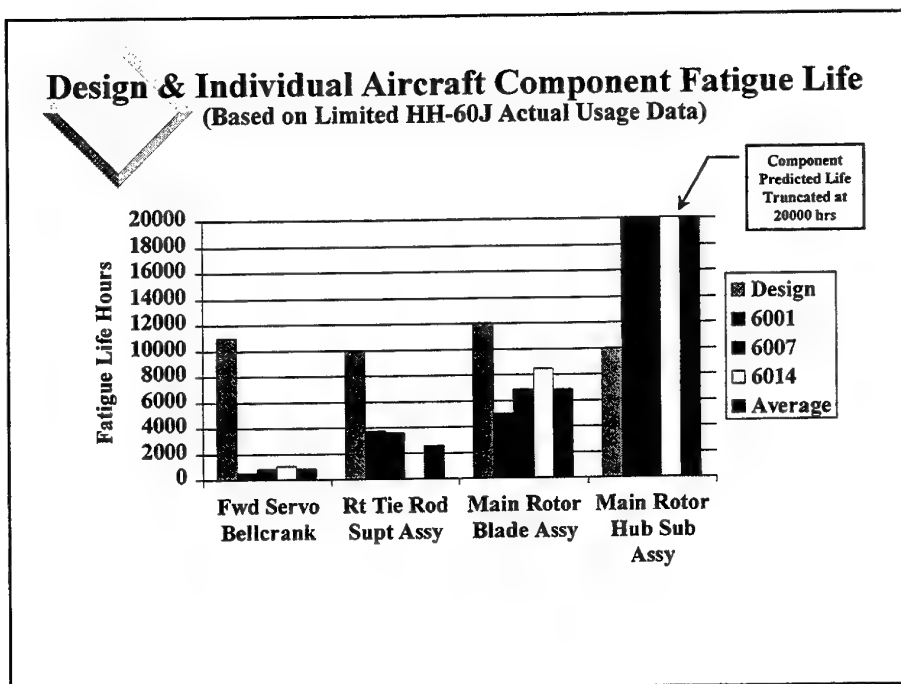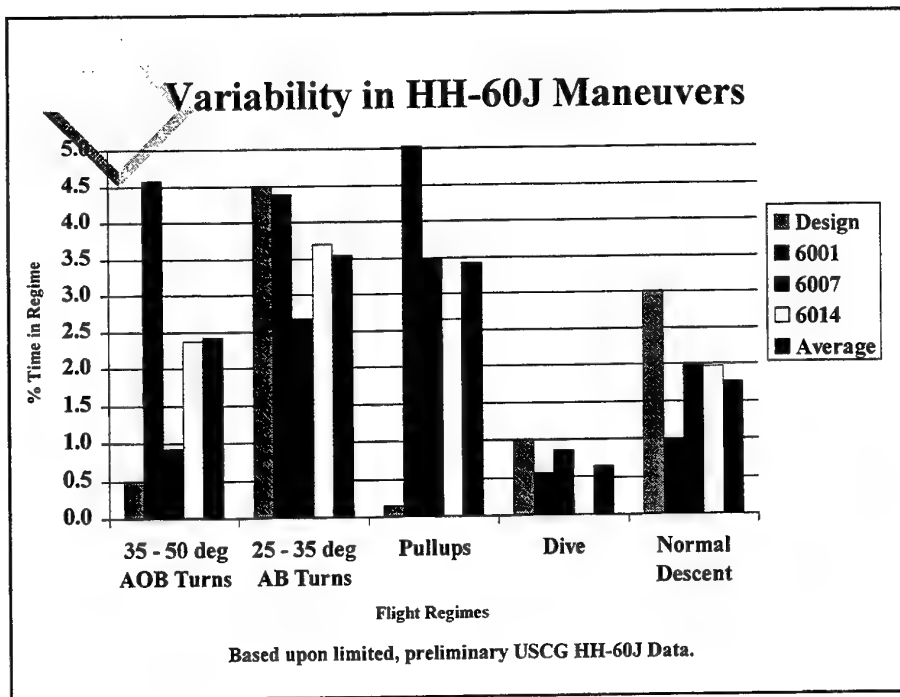## United States Coast Guard HH-60J STRUCTURAL USAGE MONITORING EVALUATION

TEAM HAWK MEETING

February 17, 1999

David White (Extra Slides) - 1

Variability in HH-60J Maneuvers

Based upon limited, preliminary USCG HH-60J Data.

Design & Individual Aircraft Component Fatigue Life
(Based on Limited HH-60J Actual Usage Data)

David White (Extra Slides) - 2

DSTO

Helicopter HUMS Workshop

Engine Gas Path Condition Assessment

by

Dr Peter Frith

Head, Engine Performance
Airframes and Engines Division
Aeronautical & Maritime Research Laboratory
Tel: 61 3 9626 7695
Fax: 61 3 9626 7083
E-mail: Peter.Frith@dsto.defence.gov.au

Melbourne, Australia

February 16-17, 1999

DSTO

OUTLINE

- DSTO gas path condition assessment activities

- HUMS related T700 engine activities

- Power Performance Index (PPI)

- T700 model based power check

- T700 MATLAB-Simulink twin engine model

- Summary

Frith - 1

DSTO

Major Gas Path Condition Assessment Projects

- **TF30 engines in F111**

  - Engine Diagnostic and Acceptance System (EDAS)
    (for engine test cells)
  - Interactive Fault Diagnosis Isolation System (IFDIS)
    (for flight line troubleshooting)

- **F404 engines in F/A-18**

  - Automated Diagnostic and Acceptance Test System (ADATS)
    (for engine test cells)

- **T700 engines in Black Hawk, Seahawk and Seasprite**

  - Model-based power check
    (for future HUMS)
  - Model-based diagnostics
    (for future HUMS)

DSTO

Main Technical Activities

- Facilitate implementation of automated engine diagnostic,
  test acceptance and data acquisition systems

- Acquire and classify engine data into fault-signature data-bases

- Develop and validate advanced adaptive component based
  thermodynamic engine models

- Investigate and develop the use of neural and fuzzy logic techniques
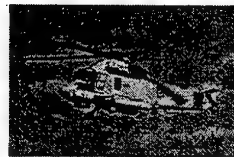 to identify fault signatures against the observed measurement
  and model uncertainty

Frith - 2

DSTO

ADF Helicopters with T700 turboshaft engines

Black Hawk   Seahawk   Seasprite

T700

DSTO

HUMS Related T700 Engine activities.

- On-going assessment of current HIT and power checks

- Assessment of Power Performance Index (PPI) for US Navy HIDS
  (a TTCP AER-TP-7 collaborative activity)

- Development of model-based power check
  (a TTCP AER-TP-7 collaborative activity)

- Development of MATLAB-Simulink twin engine model

- Development of model-based diagnostics

Frith - 3

DSTO

Assessment of GE Power Performance Index (PPI)

- PPI uses a simple TGT versus TQ reference curve
  - represents minimum acceptable performance
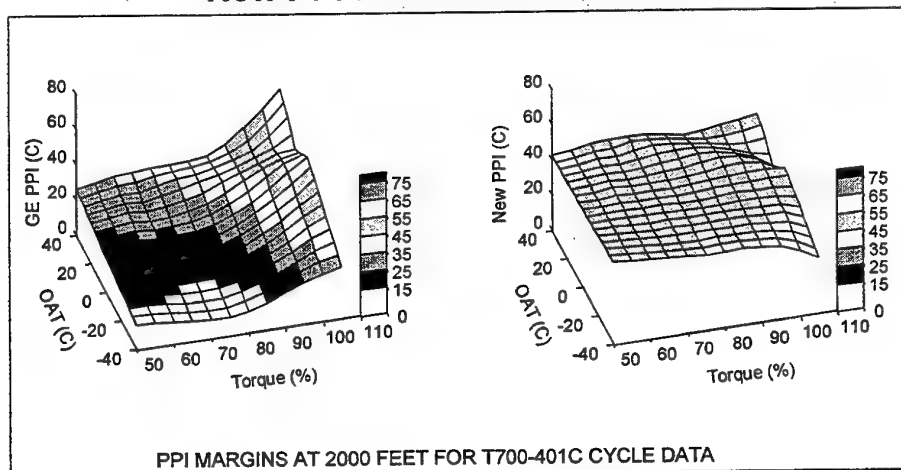
RESULTS

- Restricted to sea- level and low to medium power levels

- Developed new version applicable to 14000 feet

- Established best capture window

  - endurance / range cruise
  - 12 second window

Produces useful end of flight condition indicator

DSTO

New PPI in HIDS SH-60 HUMS

PPI MARGINS AT 2000 FEET FOR T700-401C CYCLE DATA

Sensitive to OAT correction

DSTO

T700 Model-Based Power Check

Aim: to predict the power available from twin engine helicopter installations
when the two engines operate with varying levels of component degradation
(i.e. significantly different to specification performance)

Roles: Maintenance - Engine Removal

Operational - Mission Planning

Model : Based on NASA T700 dynamic model (Fortran)

Developed open-loop single engine degradation version

Validated against specification and test data

Results: Good match to specification and US Navy test data across power range

Dual engine power can be generated from steady-state single engine results

Provides Dual Engine Power Check and Mission Planning Capability

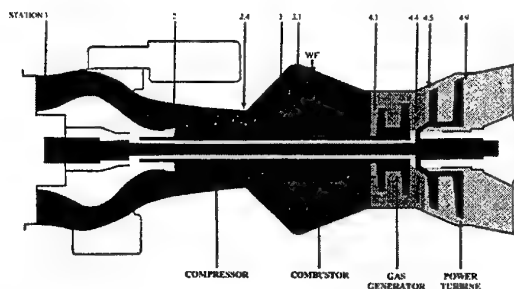---

DSTO

Single Engine Open-Loop Degradation Model

FIDELITY vs SIMPLICITY

COMPONENT EFFECTS:

Intake
Scavenge/Anti-ice/Starting Bleeds
Compressor
Compressor/Customer Bleeds
Combustor
Gas Generator Turbine
Power Turbine
Exhaust

TWO PARTS:

Engine to Engine Variations
Component Degradation

Fidelity of T700 Degradation model is okay for Power Check

Frith - 5

DSTO

Data-Bases for Model Validation

OEM Models: GE T700 Specification Models
- - 701A, - 401, - 401C

Operational : AUS Army Manual HIT and Power Checks

TTCP: US Navy HIDS Patuxent Flight Trials
US Navy Trenton Test Cell Data
- - 700, - 401, - 401C
- fleet rejected engines

Overhaul: Pacific Turbine Test Cell Data
- - 701A modules and engines
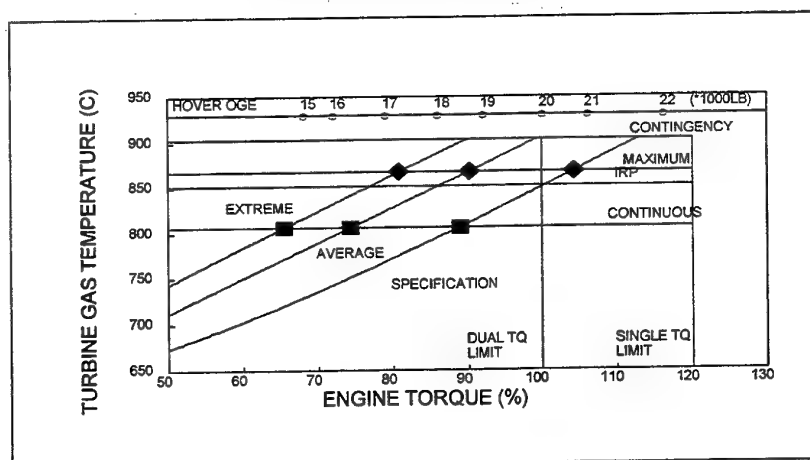- pre and post maintenance tests

Future: Fault implant test program
- - 701A engine available
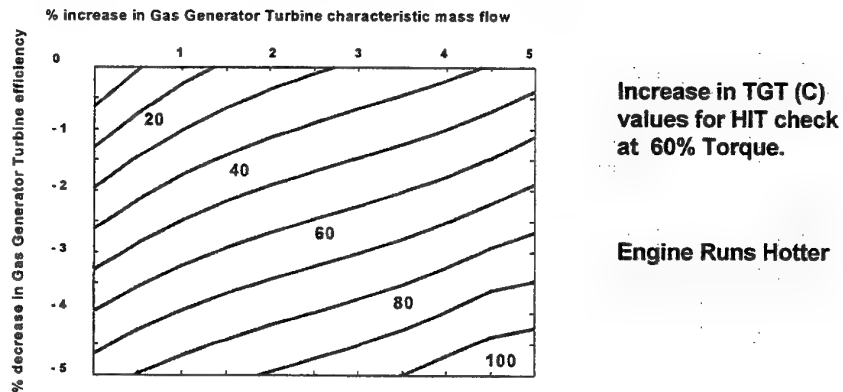
Benefit from Fault Implant Test Program

DSTO
Maximum Power Available - Two Engine
{4000 ft and 35C}

Developing version to be run in Excel

DSTO

Effect of Varying Gas Generator Turbine Degradation

% increase in Gas Generator Turbine characteristic mass flow

Increase in TGT (C)
values for HIT check
at 60% Torque.

Engine Runs Hotter

Use to Relate HIT values to Power Check

DSTO

MATLAB - Simulink Twin Engine Model

Aim: to develop enhanced T700 modelling tool
- true twin engine transient model
- readily interfaced with modern software tools

Simulink: improvement over Fortran model / interactive simulation
visual display of engine model / construct by 'drag-an drop
interface with signal processing, fuzzy logic, real-time workshop toolboxes
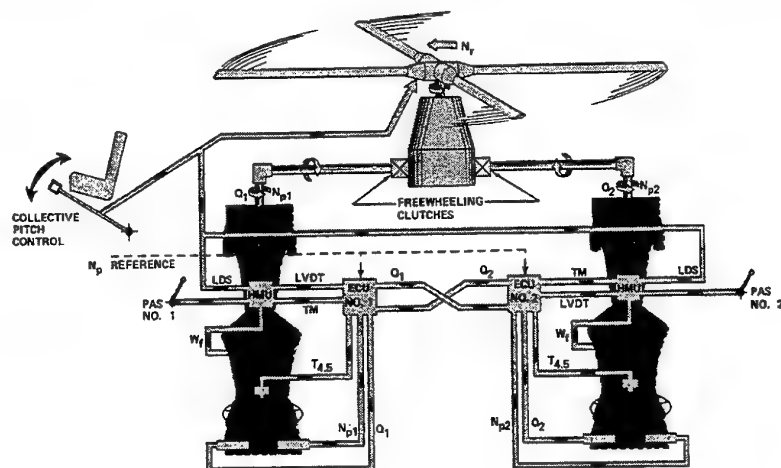
New Capabilities: diagnosis from transient flight data
engine related accident investigations
retrofitting FADEC

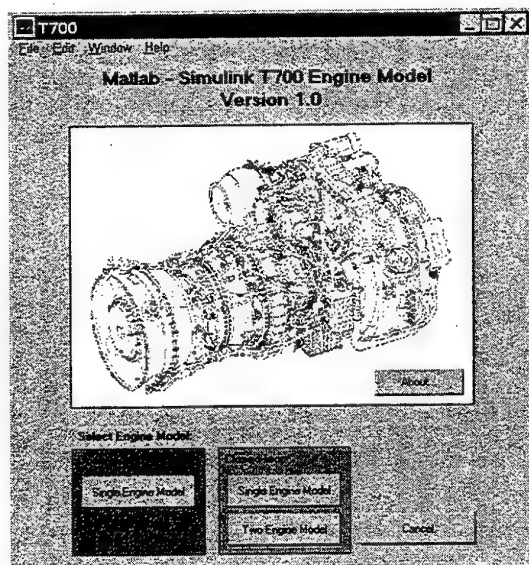**What next?** Validate against HIDS SH-60 flight test data

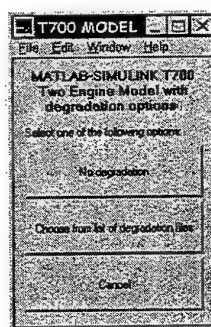Okay for what-if studies - further validation for diagnostics
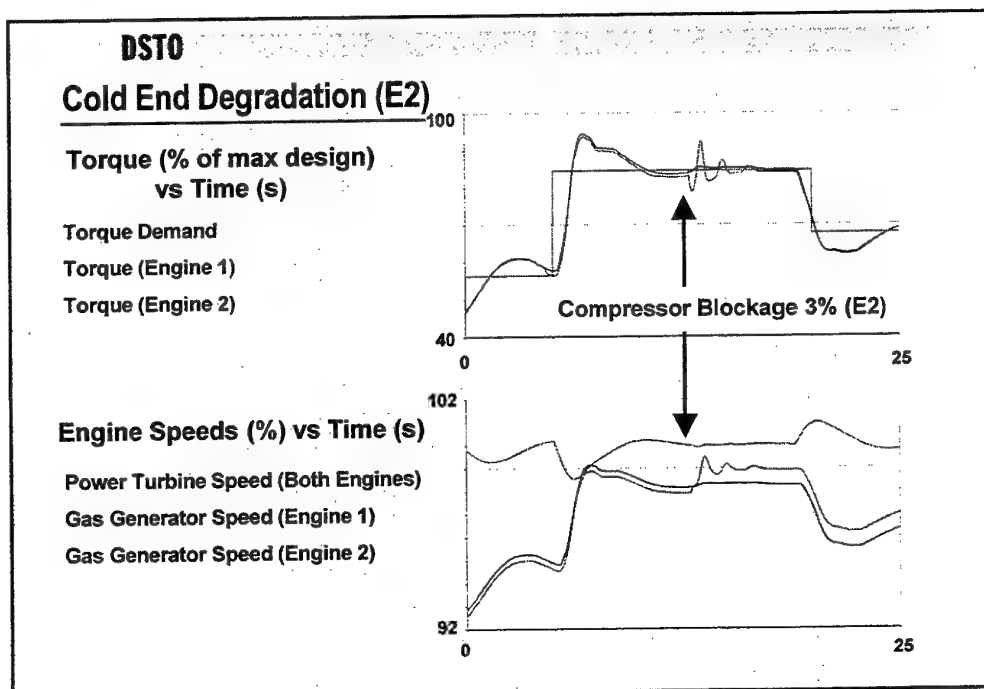
T700 Twin Engine Installation

Title Interface

...and Degradation Interface

Frith - 8

Frith - 9

Frith - 10

Hot End Degradation (E1)

DSTO

Torque (% of max design) vs Time (s)

Torque Demand
Torque (Engine 1)
Torque (Engine 2)

Torque Split

Engine Speeds (%) vs Time (s)

Power Turbine Speed (Both Engines)
Gas Generator Speed (Engine 1)
Gas Generator Speed (Engine 2)
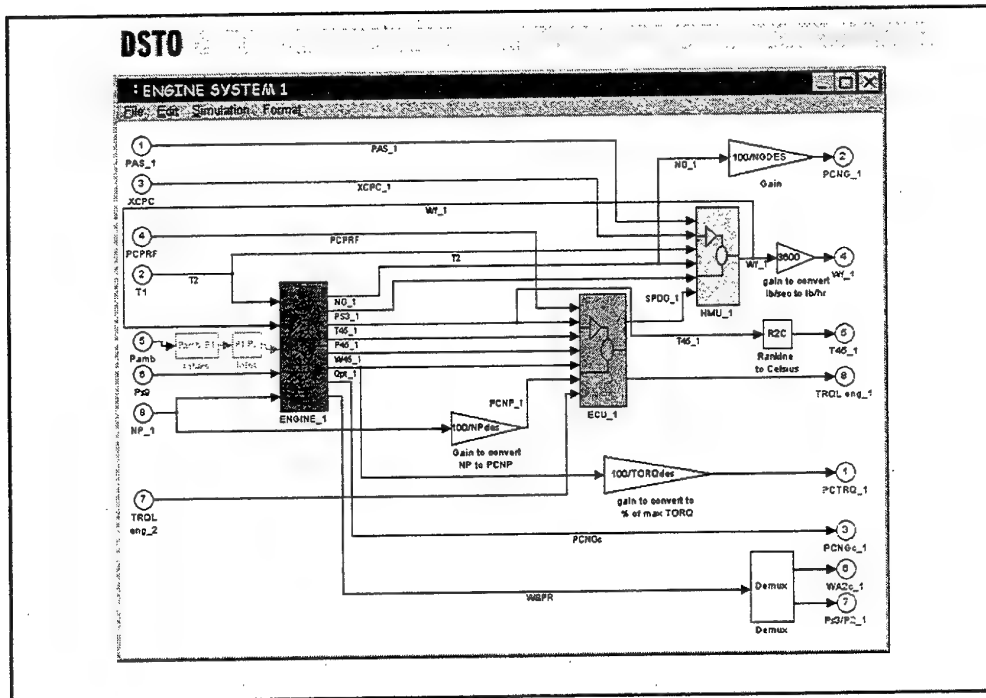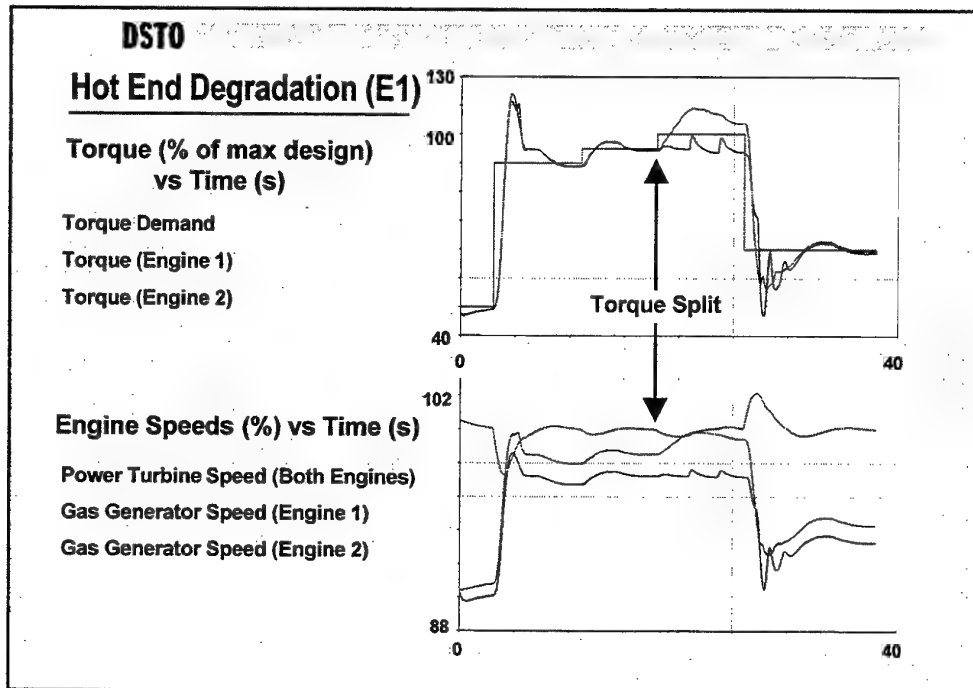
DSTO

Summary

- Power Performance Indicator provides extended HIT check
  - end of flight condition indicator - trendable
- Power Check requires model-based approach
- Developed T700 component degradation model
  - validated against specification and test data
  - provides dual engine power check / mission planning capability
- Developed enhanced T700 modelling capability - Simulink model
  - true twin engine transient model
- Currently developing a model-based diagnostic capability

Workshop on Helicopter Health and Usage Monitoring Systems, Melbourne, Australia, February 1999 - Part 2.

Graham F. Forsyth (Editor)

AUSTRALIA

DEFENCE ORGANISATION

Task Sponsor
HQ-ASG SO1-LOG Oakey

S&T Program
Chief Defence Scientist ⎫
FAS Science Policy ⎬ shared copy
AS Science Corporate Management ⎭
Director General Science Policy Development
Counsellor Defence Science, London (Doc Data Sheet)
Counsellor Defence Science, Washington (Doc Data Sheet)
Scientific Adviser to MRDC Thailand (Doc Data Sheet)
Director General Scientific Advisers and Trials/Scientific Adviser Policy and Command (shared copy)
Navy Scientific Adviser
Scientific Adviser - Army
Air Force Scientific Adviser
Director Trials

Aeronautical and Maritime Research Laboratory
Director

Chief of Airframes and Engines Division
Research Leader Propulsion
Head Helicopter Life Assessment
Task Manager – Graham F Forsyth
Author(s):   10 copies

DSTO Library
Library Fishermens Bend
Library Maribyrnong
Library Salisbury (2 copies)
Australian Archives
Library, MOD, Pyrmont (Doc Data sheet only)

Capability Development Division
Director General Maritime Development

Director General Land Development
Director General C3I Development (Doc Data Sheet only)

Navy

SO (Science), Director of Naval Warfare, Maritime Headquarters Annex, Garden Island, NSW 2000. (Doc Data Sheet only)

Army

ABCA Office, G-1-34, Russell Offices, Canberra (4 copies)
SO (Science), DJFHQ(L), MILPO Enoggera, Queensland 4051
NAPOC QWG Engineer NBCD c/- DENGRS-A, HQ Engineer Centre Liverpool Military Area, NSW 2174

Air Force

Officer In Charge Aircraft Structural Integrity – RAAF Williams

Intelligence Program

DGSTA Defence Intelligence Organisation

Acquisitions Program

DAASPO

Corporate Support Program (libraries)

OIC TRS, Defence Regional Library, Canberra
Officer in Charge, Document Exchange Centre (DEC) (Doc Data Sheet and distribution list only)
*US Defence Technical Information Center, 2 copies
*UK Defence Research Information Centre, 2 copies
*Canada Defence Scientific Information Service, 1 copy
*NZ Defence Information Centre, 1 copy
National Library of Australia, 1 copy

UNIVERSITIES AND COLLEGES

Australian Defence Force Academy
Library
Head of Aerospace and Mechanical Engineering
Deakin University, Serials Section (M list), Deakin University Library, Geelong, 3217 (Senior Librarian, Hargrave Library, Monash University
Librarian, Flinders University

OTHER ORGANISATIONS

NASA (Canberra)
AGPS
CASA – Canberra

OUTSIDE AUSTRALIA

ABSTRACTING AND INFORMATION ORGANISATIONS
INSPEC: Acquisitions Section Institution of Electrical Engineers
Library, Chemical Abstracts Reference Service
Engineering Societies Library, US
Materials Information, Cambridge Scientific Abstracts, US
Documents Librarian, The Center for Research Libraries, US

INFORMATION EXCHANGE AGREEMENT PARTNERS
Acquisitions Unit, Science Reference and Information Service, UK
Library - Exchange Desk, National Institute of Standards and Technology, US

OTHER:
CAA UK HHMAG (Secretary)

SPARES   (35 copies)

Total number of copies: 100 (+ 10 DocData Sheets)

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION DOCUMENT CONTROL DATA	1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE Workshop on Helicopter Health and Usage Monitoring Systems, Melbourne, Australia, February 1999 - Part 2	3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION) Document Title Abstract

4. AUTHOR(S) Graham F. Forsyth (Editor)	5. CORPORATE AUTHOR Aeronautical and Maritime Research Laboratory PO Box 4331 Melbourne Vic 3001 Australia

6a. DSTO NUMBER DSTO-GD-0197 (Part 2)	6b. AR NUMBER AR-010-839	6c. TYPE OF REPORT General Document	7. DOCUMENT DATE March 1999

8. FILE NUMBER M2/997	9. TASK NUMBER ARM96/082	10. TASK SPONSOR SO1 LOG ASG	11. NO. OF PAGES 144	12. NO. OF REFERENCES

13. DOWNGRADING/DELIMITING INSTRUCTIONS	14. RELEASE AUTHORITY Chief, Airframes and Engines Division

15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

Approved for public release

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE CENTRE, DIS NETWORK OFFICE, DEPT OF DEFENCE, CAMPBELL PARK OFFICES, CANBERRA ACT 2600

16. DELIBERATE ANNOUNCEMENT

No Limitations

17. CASUAL ANNOUNCEMENT	Yes

18. DEFTEST DESCRIPTORS

Health and Usage Monitoring Systems, Helicopter Maintenance, Airworthiness, Condition Monitoring

19. ABSTRACT

Over the last 10 years, helicopter Health and Usage Monitoring Systems (HUMS) have moved from the research environment to being viable systems for fitment to civil and military helicopters. In the civil environment, the situation has reached the point where it has become a mandatory requirement for some classes of helicopters to have HUMS fitted. Military operators have lagged their civil counterparts in implementing HUMS, but that situation appears set to change with a rapid increase expected in their use in military helicopters.

A DSTO-sponsored Workshop was held in Melbourne, Australia, in February 1999 to discuss the current status of helicopter HUMS and any issues of direct relevance to military helicopter operations. This second part contains a list of those attending and a number of papers not received in time for publication before the event.